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HYDRAULIC MODELING OF LOW FLOWS AMERICAN FORK CREEK, TIMPANOGOS CAVE NATIONAL MONUMENT, UTAH

By

Michael W. Martin
and
William L. Jackson

NATIONAL PARK SERVICE
WATER RESOURCES DIVISION
FORT COLLINS, COLORADO

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INTRODUCTION

Timpanogos Cave National Monument, located in the Wasatch Mountains south of Salt Lake City, and north of Provo, Utah, was established in 1922 to preserve a multiple-cave system containing uncommon flowstone structures. The administrative boundary of the Monument includes the cave entrance located high on the south wall of the American Fork Canyon, and a portion of the valley floor, including an approximate 2/3 mile reach of the American Fork Creek.

The portion of the creek that flows within the monument is subject to some degree of dewatering due to upstream bypass flows for power generation. The bypass facility is owned and operated by Pacificorp, and is designated the American Fork Hydroelectric Project #696, hereafter referred to as "the project". The project is currently operating on a minor permit issued by the Federal Power Commission after the original license expired on June 30, 1970. The minor license is due to expire on October 31, 2000 and therefore, Pacificorp is currently seeking a new license with the Federal Energy Regulatory Commission (FERC).

The project consists of a diversion dam and intake structure, a steel flowline approximately 2.33 miles long, a riveted steel penstock, and a powerhouse. The intake structure is located about one mile upstream of the monument boundary and is capable of

diverting up to 26 cubic feet per second (cfs). Pacificorp currently holds a non-consumptive water right from American Fork Creek for 50 cfs with a priority date of 1918. The existing plant was taken off line on May 10, 1993 due to a break in the flowline. A plan is in place to repair and reinforce the flowline and install an automatic emergency closure system.

All structures associated with the project are authorized to occupy United States Forest Service (USFS) land under the Special Agreement signed May 13, 1907. The present flowline alignment is almost entirely within the Lone Peak Wilderness. However, about 1400 feet pass within the monument boundary, and an additional 2100 feet of the flowline is within 300 feet of the monument, and directly above it on steep, unstable slopes.

SETTING AND BACKGROUND

The American Fork Creek headwaters in the Wasatch Mountains and flows west through American Fork Canyon at a grade of about four percent. Silver Lake, the Silver Lake Flat Dam, and Tibble Fork Reservoir are all located in the upper watershed of American Fork Creek. The creek exhibits seasonal fluctuation characteristic of an intermountain aquatic ecosystem with some regulation; the annual hydrograph is driven by snowmelt between May and July with discharge supplemented by upstream reservoir releases in the summer. Peak flows of 1000 cfs have occasionally occurred but flows are more typically in the range 100 to 500 cfs. Summer flows

which are usually in the range of 15 to 439 cfs are augmented by releases from Tibble Creek Reservoir. The lowest flows in the creek occur in the Fall/Winter period and can range from 10 to 64 cfs (ERI, 1992)

A United States Geologic Survey (USGS) gaging station (#10164500) is operated on the American Fork Creek above the diversion. The period of record for this gaging station is from Oct 1, 1927 to the present. Daily flow records from this gage were used to construct both an average daily flow duration curve (Figure 1), and a 30-day, running average, low-flow frequency curve (Figure 2).

By examination of the mean daily flow duration curve it is evident that on average, streamflow exceeds the powerplant capacity of 26 cfs about 45 percent of the time (Figure 1). Consequently, operation of the powerplant at full capacity has the capability of completely dewatering the bypass reach of American Fork Creek roughly 55 percent of the time. The excess of flow generally occurs from April to August, thus for the remaining seven months, the average streamflow is often below the project capacity. Considering the low-flow frequency, there is an almost 100 percent chance that the 30-day, mean low flow will <u>not</u> exceed power plant capacity (Figure 2). All 30-day mean low-flows calculated from the record fell between November 28 and March 2.

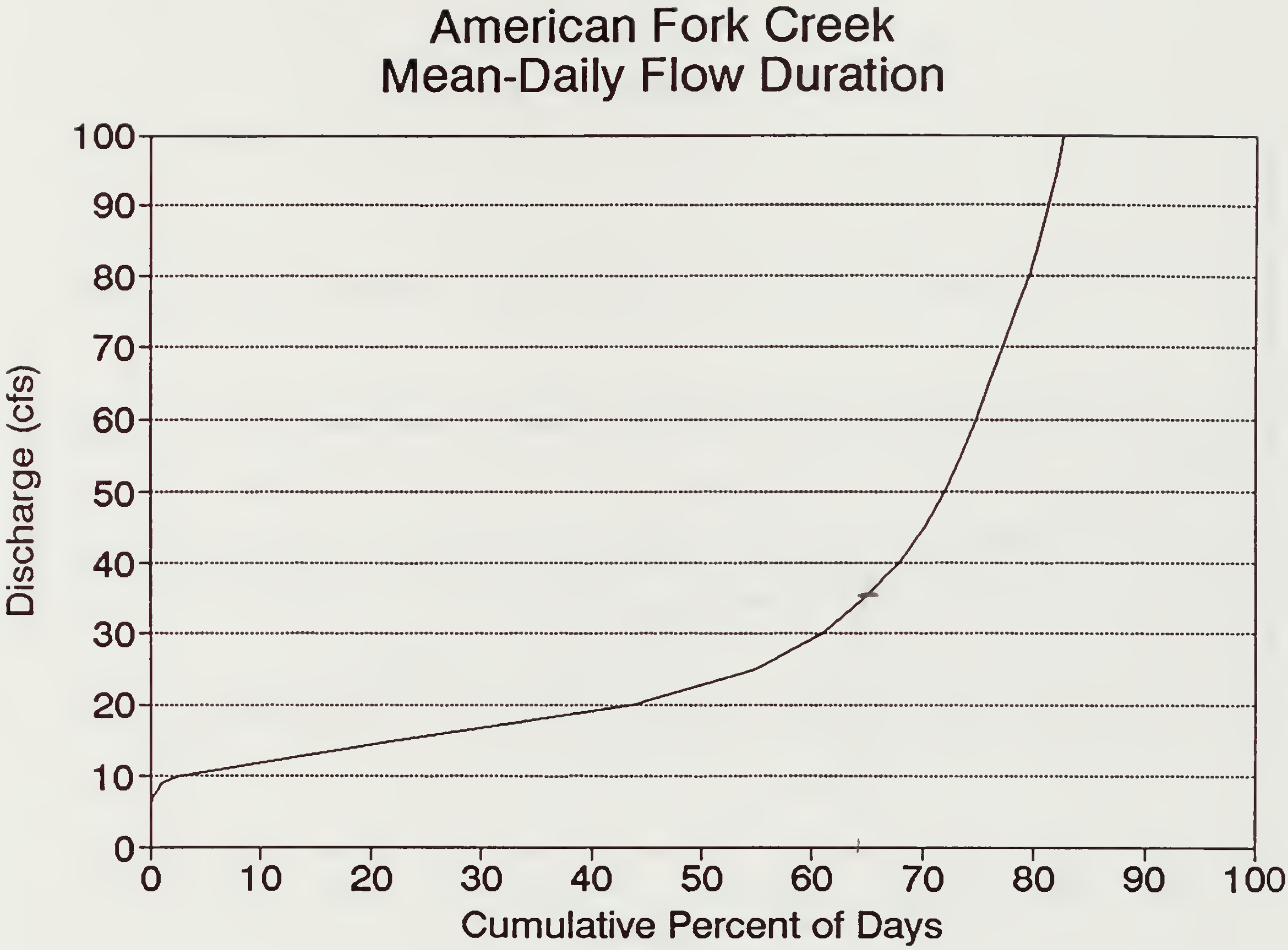


Figure 1. Mean Daily Flow Duration Curve showing percent of time in average flow years that discharge is below a certain value.

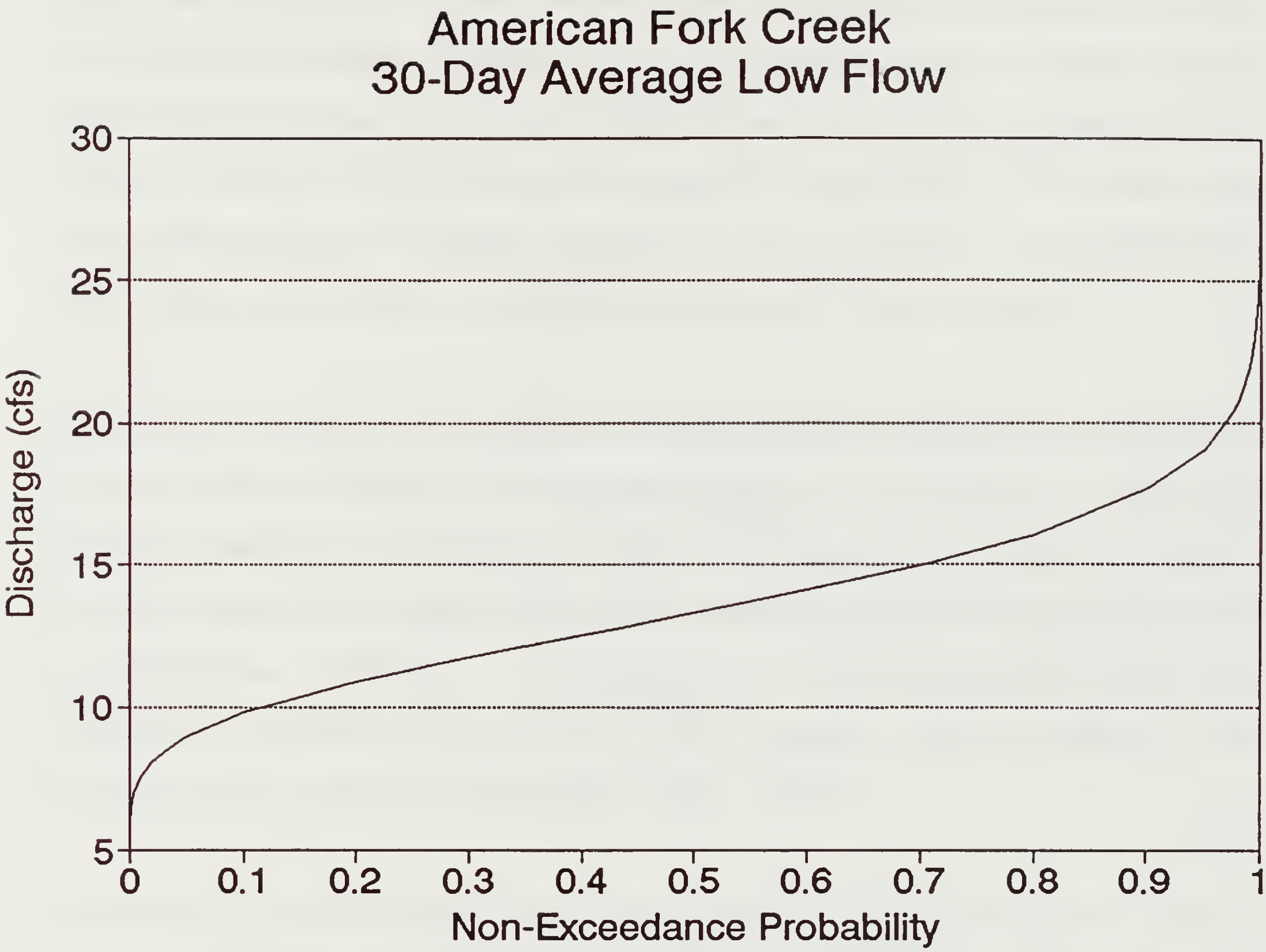


Figure 2. Non-exceedance probability curve for the running 30-day mean low flow. The curve indicates the probability that a specific mean discharge will <u>not</u> be exceeded in a 30-day period.

In 1986 the FERC was mandated to give consideration in relicensing hydropower projects to the existing environment, recreation, fish, and wildlife values affected by the project, equal to that given power and developmental objectives. The goal of this mandate is to balance what are often competing uses of a waterway. The FERC was also empowered to consider whether or not a project is consistent with State and Federal comprehensive plans, (18 CFR 16).

As a result of the 1986 mandate, Pacificorp was required to consult with the Utah Division of Wildlife Resources and the U.S. Fish and Wildlife Service to perform a study to determine the need, if any, of a minimum flow release into the bypass reach for maintenance of the fisheries resource. Consequently, a collaborative study was conducted focusing on the 2.4 mile bypass reach between the diversion dam and the powerhouse (ERI, 1992).

The study found an equal or greater brown trout population within the bypass reach as compared to below the powerhouse. The average minimum flow in the bypass reach between 1986 and 1991 was 3.87 cfs, and it was concluded that this discharge provided favorable conditions for the brown trout population (ERI, 1992). Based on existing information of fish populations, habitat preference and availability, a minimum bypass flow of 4 cfs was proposed as sufficient to support the brown trout population. In 1993 Pacificorp installed a water control device at the diversion dam to maintain a continuous minimum flow of 4 cfs in the bypass reach.

In addition to fisheries resources, both the National Park Service and the USFS are concerned with managing the aesthetic resources of the area. A primary objective of the National Monument is to preserve resources while providing for public use and enjoyment in such a way as to leave those resources unimpaired for future generations. It is this consideration of resource values, specifically aesthetic values that necessitated this analysis.

The basic premise of this analysis is that the aesthetic attributes of flow, e.g. sight, sound, movement, expression of hydraulic features, etc., vary with discharge. As discharge increases the wetted part of the channel increases in width and depth. At some discharge, a given channel bed will become "full" and additional increases in flow will increase the depth and velocity faster than it will increase the width. One goal of this analysis was to predict at what discharge(s) different reaches of the American Fork Creek become "full", or more precisely, at what flow range is the rate of top width increase optimized. The overall objective of this analysis is to develop the information needed to evaluate alternative flows in relation to their hydraulic expression (i.e. width, depth, velocity) in the channel.

THE HYDRAULIC ANALYSIS

METHODS

A stream channel survey encompassing three reaches of the American Fork Creek was conducted in November of 1996. Two of the three reaches, the test and control were chosen on precedent, these being the reaches that were used for the fisheries resource study. As the names imply, the test reach is subject to dewatering, being located just downstream of the diversion, and the control reach is located below the penstocks where all diverted flow is returned to the mainstem. The third reach, which is of the greatest interest to the monument, was located in the Swinging Bridge Picnic Area and was chosen because of the high visitor exposure. Four cross sections were surveyed in each the control and the test reach and six cross sections were surveyed in the picnic reach.

These cross section data were used to conduct hydraulic modeling analysis for the separate reaches. The flow present at the time of the survey, 32 cubic feet per second (cfs), was used to calibrate HEC-RAS, an Army Corps of Engineers step backwater numeric model. After reasonable agreement between the measured and predicted water surface elevations (<0.2 ft), a series of low flows were modeled through the two reaches to predict the effect that varying flows would have on the hydraulic variables: top width, average velocity, and maximum depth.

RESULTS

The graphic representations of the results are grouped by reach and cross section and are included in appendix A. The four cross sections of each the control and test reach, are labeled consecutively XS1 through XS4, starting downstream. The six cross sections from the picnic reach are labeled XS4 to XS9 starting downstream. Each reach is depicted with a planimetric view of the survey data established with separate, arbitrary coordinates. Each cross section is depicted with a photo-reproduction marking its approximate location.

Modeling results are presented as predicted water surfaces for discharges of 4, 10, 20 and 32 cfs, superimposed on cross section plots (looking downstream). Additionally, three rating curves per cross section were developed using the discharges of 2, 4, 6, 8, 10, 12.5, 15, 17.5, 20, 25, and 32 cfs. The hydraulic variables of top width, maximum depth, and average velocity are presented as functions of discharge. If the rate of change of any of these dependent variables changes substantially with changing discharge, it is evident on the rating curve in the form of an "inflection" point, or a change in slope of the function. Reported inflection points were determined from visual inspection and interpolation.

Tables 1, 2, and 3 provide a summary of the approximate flows at which inflection points were identified for each variable at each cross section (Station). Discharges that coincide with very

distinct inflection points are marked with an asterisk. All other values corresponded with moderately to weakly evident inflection points.

Control Reach

Table 1. Approximate discharge(s) in cubic feet per second, where an inflection point(s) was determined at four stations (cross sections) within the control reach for the following hydraulic variables. Asterisk identifies distinct inflection point.

Station	Top Width	Max Depth	Avg Vel
1	7, 25*	6, 25	7, 20
2	8*	7	4*
3	10	10	6, 20
4	4*, 8	6	7, 17

Test Reach

Table 2. Approximate discharge(s) in cubic feet per second where an inflection point(s) was determined at four stations (cross sections) within the test reach for the following hydraulic variables. Asterisk identifies distinct inflection point.

Station	Top Width	Max Depth	Avg Vel
1	4, 15*	15	12
2	10	10	7, 17
3	4*, 20*	6, 15	7, 15
4	12, 20*	7, 15	6, 15

12-15

Picnic Reach

Table 3. Approximate discharges(s) in cubic feet per second where an inflection point(s) was determined at six stations (cross sections) within the picnic reach for the following hydraulic variables. Asterisk identifies distinct inflection point.

Station	Top Width	Max. Depth	Avg. Vel.
4	8	8	6, 25*
5	8	10	8*
6	25	6	6
8	6, 17	6	4, 17.5*
8	17-20*	6	8
9	4, 20*	6	15

5-17

DISCUSSION

STREAM CHANNEL MORPHOLOGY

The reach of the American Fork Creek that passes within the vicinity of TICA is characterized by a pool-riffle-run morphology. Within individual reaches, an "inner" channel or a low-flow channel exists, and was most apparent in the picnic reach, specifically at stations 4, 5, 6, and 9 (Appendix A). Step-backwater analysis indicates that a discharge of between 5 and 10 cfs is required to fill this low-flow channel. Any increase in discharge beyond this amount will serve to fill the channel bed of these reaches by increasing the top width faster than the depth.

Extrapolating this relationship, it can be deduced that certain channel forms undergo a more rapid change in appearance with

steadily increasing flows. For instance, as discharge increases, reaches that are predominantly runs and riffles will increase in top width faster than depth, relative to reaches that are predominantly pools. This relationship will be maintained until the channel bed has been covered, at which time increases in discharge will increase the depth faster than the width and the stream will approach a "bankfull" stage.

RATING CURVES

These qualitative observations may be described quantitatively through the use of discharge rating curves. The rate of change of certain hydraulic variables as a function of changing discharge is constant until the flow level reaches a change in channel morphology. This change would be evidenced in an inflection point on the rating curve. As an example using the variable top width, at discharges below this inflection point relatively large increases of top width occur as discharge increases. At discharges above the inflection point, relatively small increases in top width occur with increasing discharge. In terms of cost/benefit, additional increases in discharge above the inflection point provide diminishing returns for the selected parameter. Consequently, the discharge range that produces the inflection could be considered the "optimal" range for the chosen parameter.

Rating curve analysis of the three hydraulic variables; top width, maximum depth, and average velocity, produced results with a fairly

high degree of both reach-to-reach and cross section-to-cross section variability. Roughly half of the rating curve plots had two inflection points for both the top width and the average velocity. The lowest discharge where an inflection point was detected was 4 cfs, and this occurred at cross sections 3, 4, and 9 of the test, control, and picnic reaches, respectively. The highest discharge where an inflection point was observed (up to 32 cfs, the highest modeled flow) was 25 cfs, and this occurred at cross section 1 at both the control and the picnic reach (Appendix A). Breaking down the modeled flow range, we see that a discharge of 10 cfs would include 38 of the 60 inflection points for all three variables in the three reaches, and a discharge of 20 cfs would include 56 of the 60 inflection points.

Top width was the hydraulic variable whose plot displayed the most distinct inflection points. Of the 20 inflection points associated with top width, 9 of them were distinct, and the associated discharges ranged from 4 to 25 cfs.

The variable of average velocity resembled the response of top width in both the presence of distinct inflection and variability of the range that inflection occurred. Of the 22 inflection points associated with average velocity, 4 of them were distinct, and the associated discharges ranged from 4 to 25 cfs.

The rating curves for maximum depth displayed only indistinct

inflection points. However, the ranges of discharge where inflection occurred was much less variable than the other two parameters. Some inflection was observed between discharges of 6 to 10 cfs in 13 of the 14 cross sections. The remaining cross section displayed inflection at 15 cfs.

CONCLUSIONS

A minimum discharge of 10 cfs would result in a considerable "optimization" of all three hydraulic variables over the 4 cfs previously recommended for habitat maintenance. The discharge of 10 cfs would actually result in achieving the flow-width inflection point at 11 of the cross sections in all three reaches, including 4 of the 6 cross sections in the picnic area reach. Additionally, this discharge would achieve inflection at 12 cross sections for average velocity including 5 in the picnic reach, and 13 cross sections for maximum depth including all 6 in the picnic reach.

Referring to the flow duration curve (Figure 1), 10 cfs is a flow which occurs upstream of the diversion about 97 percent of the time. In other words, without the diversion, flows would normally drop below 10 cfs only about three percent of the time. Furthermore, the low-flow frequency curve (Figure 2) indicates that there is only about a 10-12 percent chance that a mean 10 cfs discharge will not be exceeded during a thirty day period.

Considering higher flows, a minimum discharge of roughly 25 cfs

would result in achieving or exceeding the inflection points at all cross sections for all three variables. Again, referring to the flow duration curve and low-flow frequency curve (Figures 1 and 2), flows drop below 25 cfs over half the time upstream from the diversion, and there is close to a 100 percent chance that a mean 25 cfs will not be exceeded in a 30 day period.

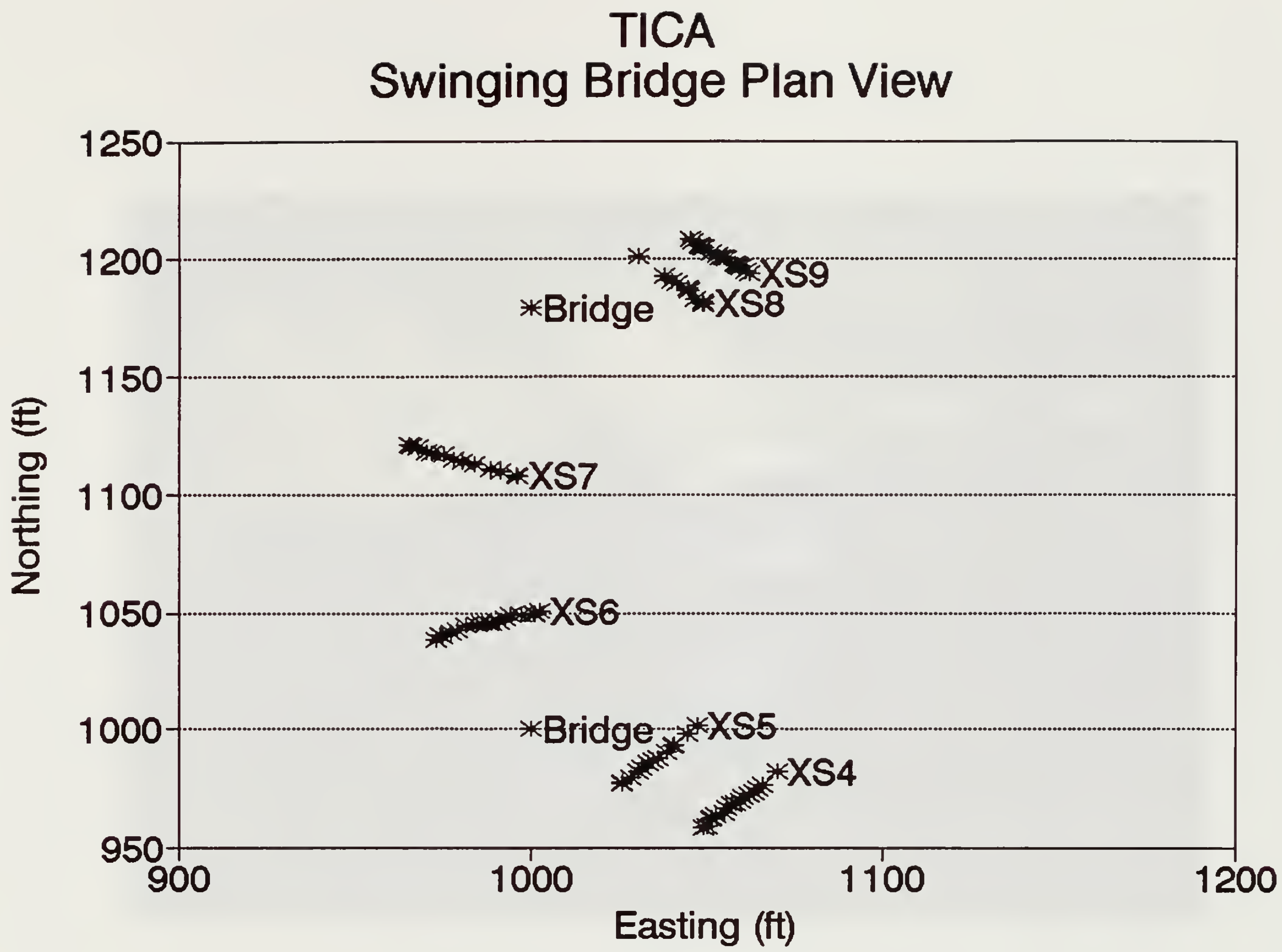
By combining power plant capacity and bypass flows in the duration and frequency analysis, we see that flows drop below 36 cfs (powerplant capacity plus 10 cfs bypass) roughly 65 percent of the time and that there is a 100 percent chance that during the low-flow period, the 30-day average will not exceed this value. Additionally, flows drop below 56 cfs (power plant capacity plus 25 cfs bypass) roughly 75 percent of the time, and again there is a 100 percent chance that during the low-flow period, the 30-day average will not exceed this value.

This analysis clearly shows that different discharges result in different expressions of flow in the channel. The analysis also shows that as the minimum flow objective increases, there is an increasing likelihood that water available for that particular year or season will constrain the ability to achieve the flow objective. Therefore, while 4 cfs may provide for fisheries maintenance in low-flow years, it may be possible to consider higher flow levels for aesthetic purposes in selected months during normal and high flow years.

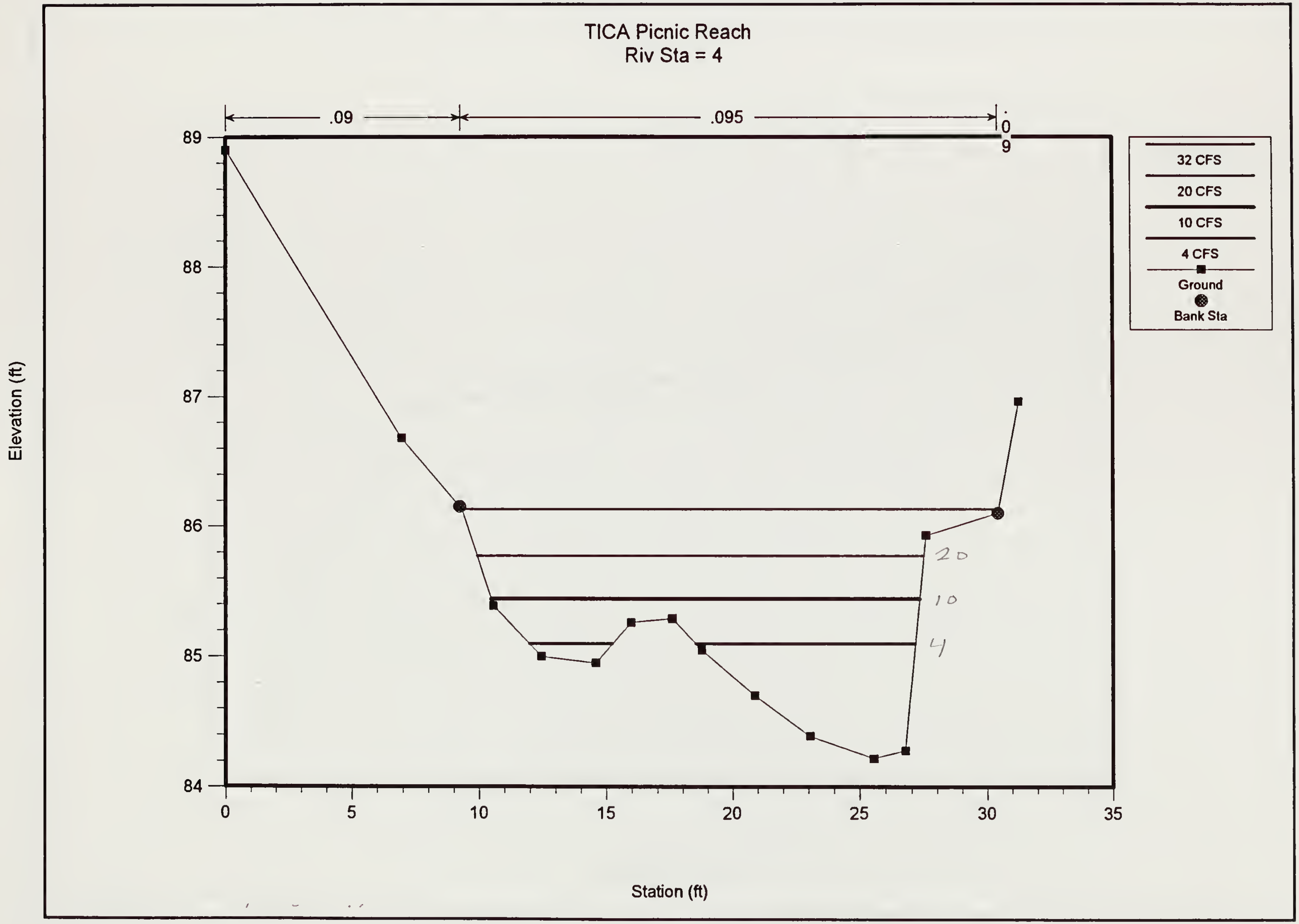
REFERENCES CITED

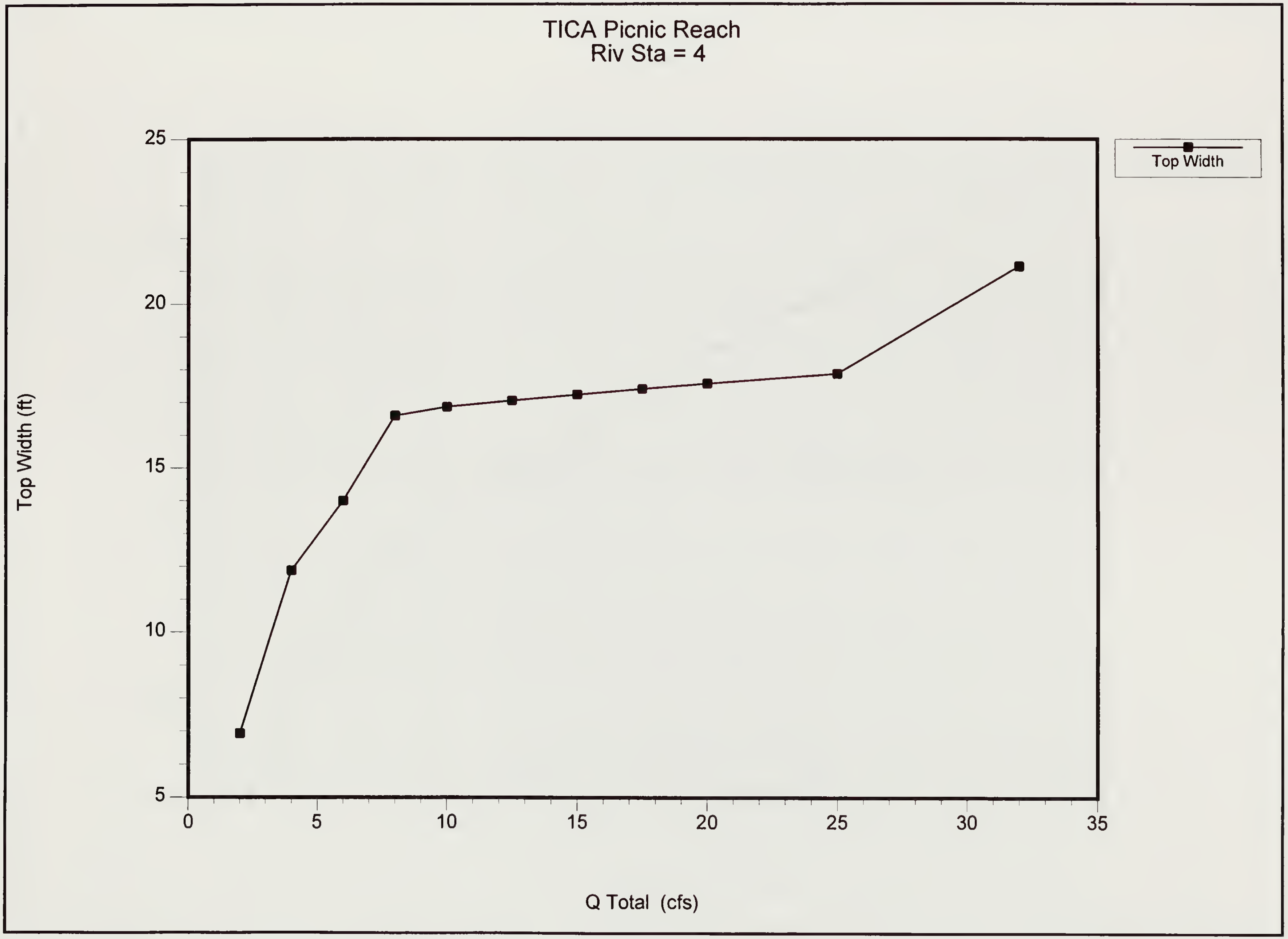
ERI, 1992. Upper American Fork Project FERC no. 696 Minimum Flow study. Ecosystem Research Institute, Logan Utah, 1992.

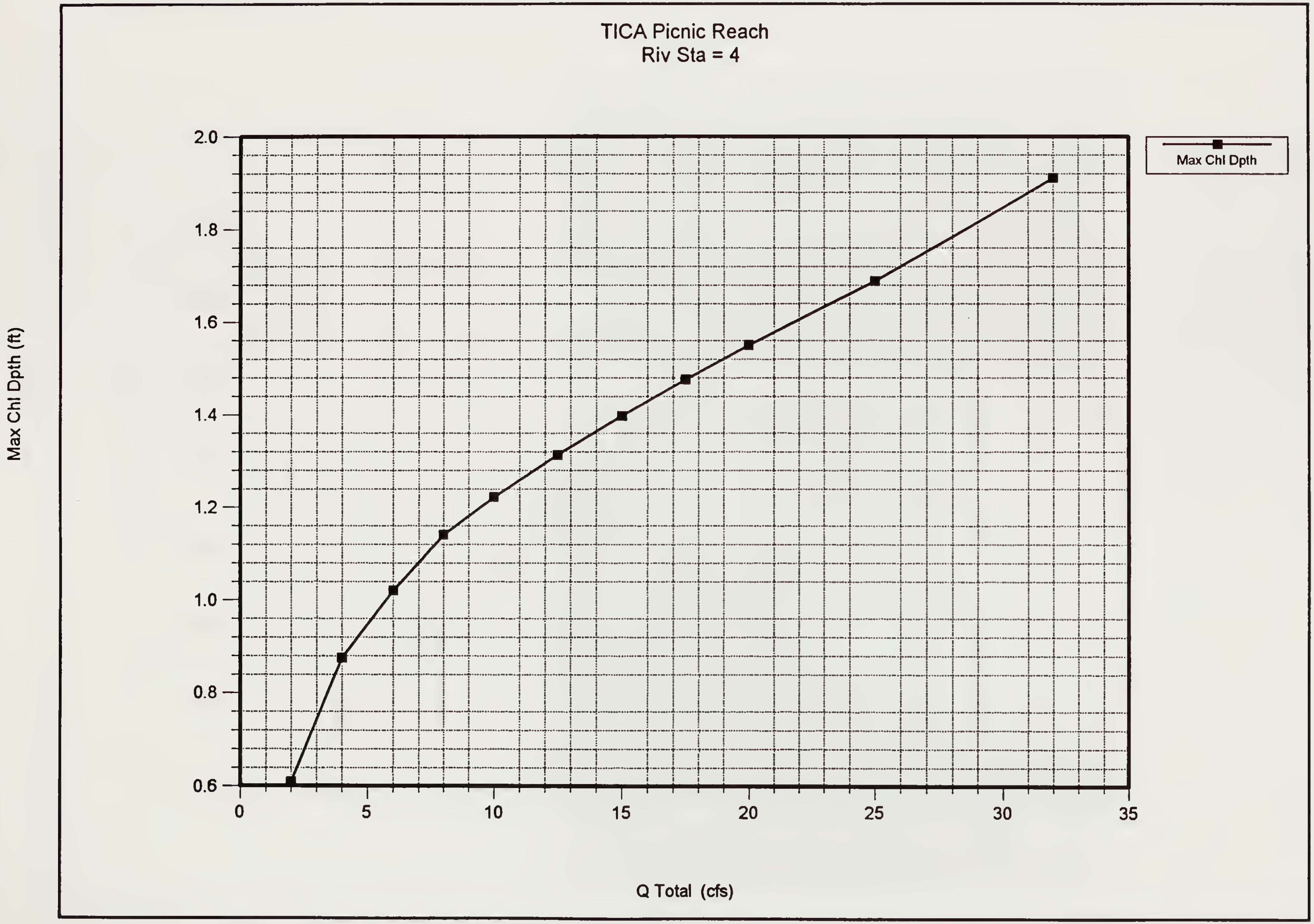
APPENDIX A

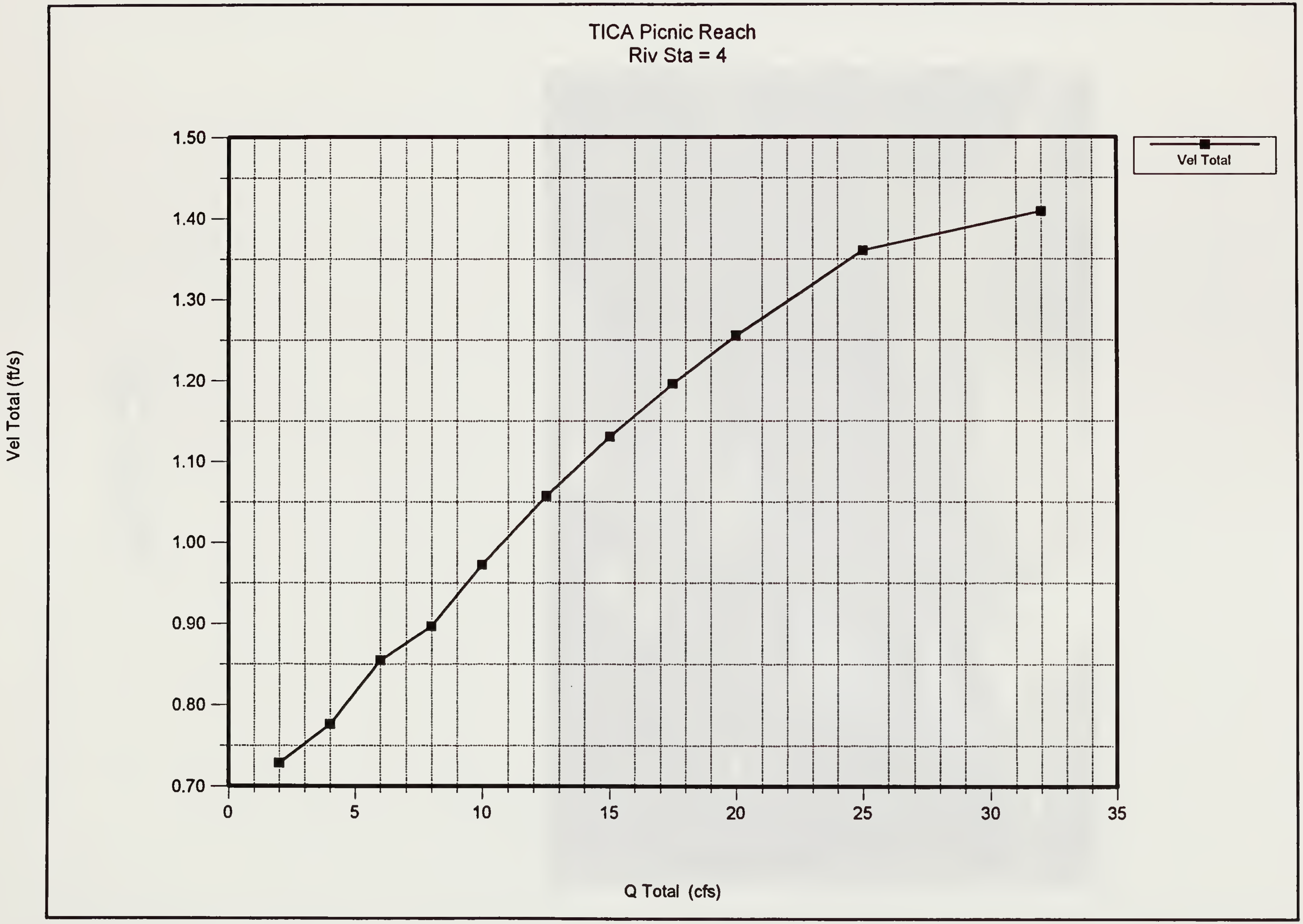

TICA
Swinging Bridge Plan View
Northing (ft)
Easting (ft)
1250
1200
1150
1100
1050
1000
950
900
1000
1100
1200
Bridge
XS9
XS8
XS7
XS6
Bridge
XS5
XS4

Picnic Area Reach
Cross Section 4

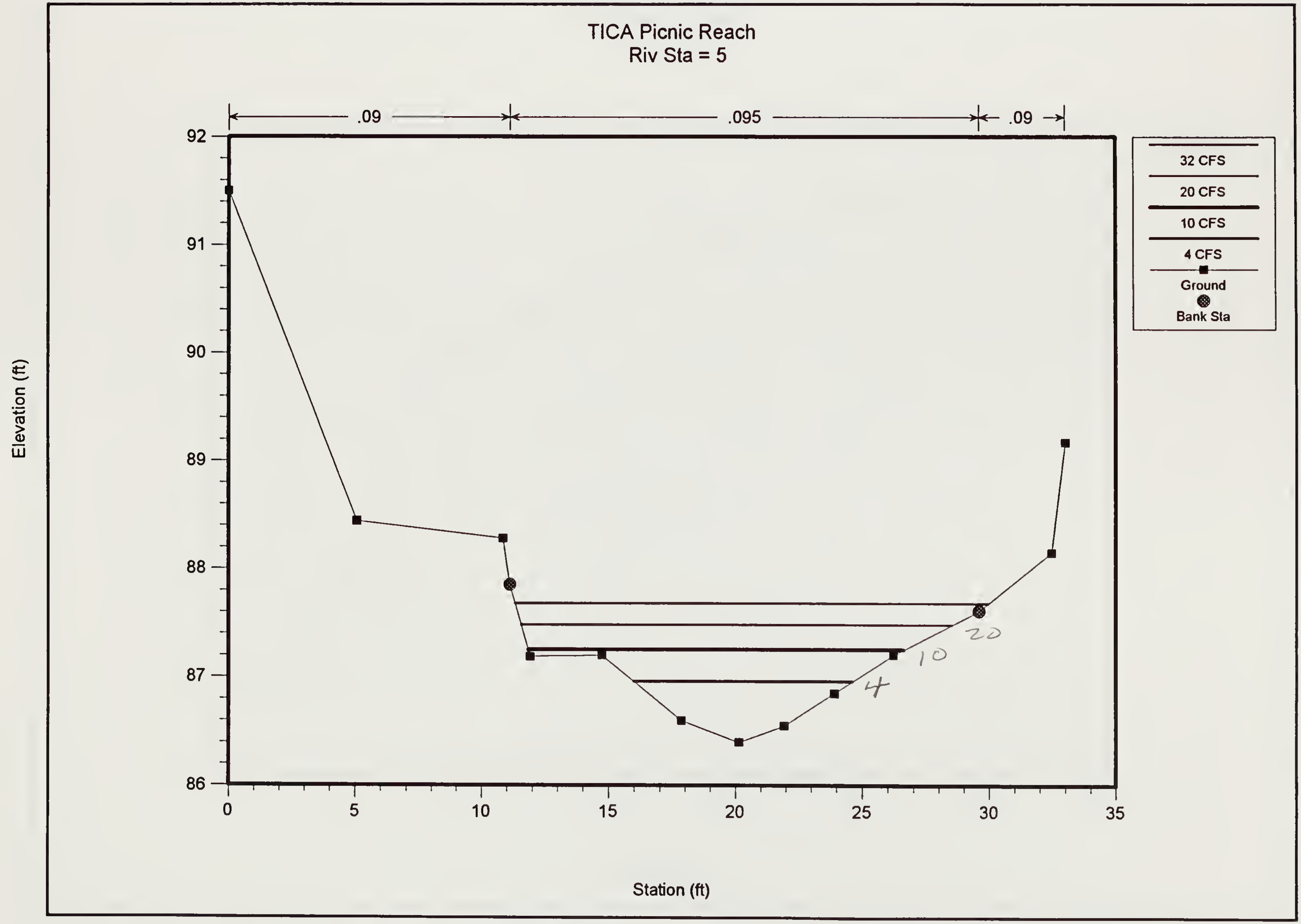

TICA Picnic Reach
Riv Sta = 4
.09
.095
.09
89
88
87
86
85
84
0
5
10
15
20
25
30
35
Elevation (ft)
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
20
10
4


TICA Picnic Reach
Riv Sta = 4
Top Width
Top Width (ft)
Q Total (cfs)
25
20
15
10
5
0
5
10
15
20
25
30
35

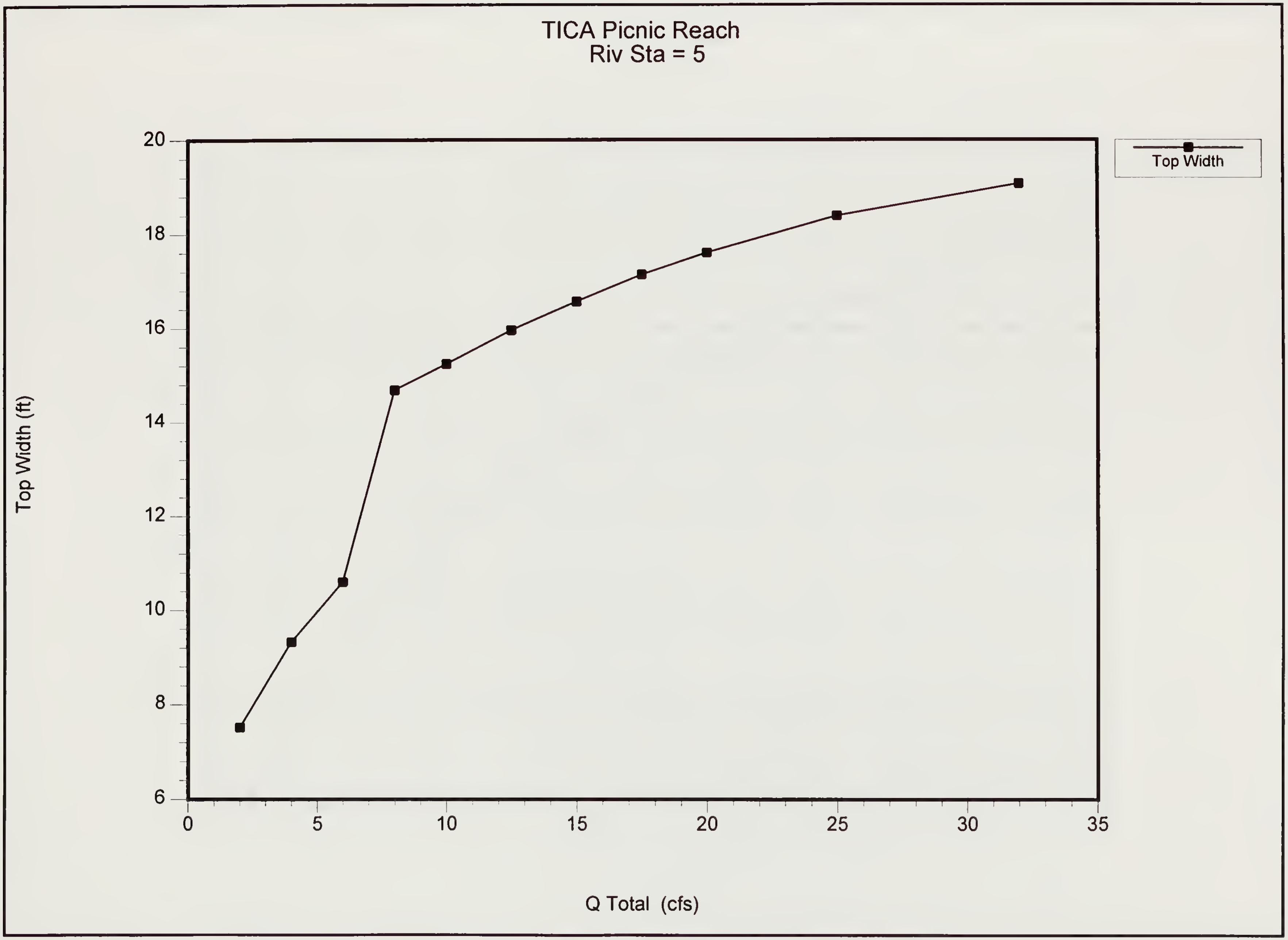

TICA Picnic Reach
Riv Sta = 4
Max Chl Dpth (ft)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)
Max Chl Dpth


TICA Picnic Reach
Riv Sta = 4
Vel Total
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0
5
10
15
20
25
30
35
Q Total (cfs)
Vel Total (ft/s)

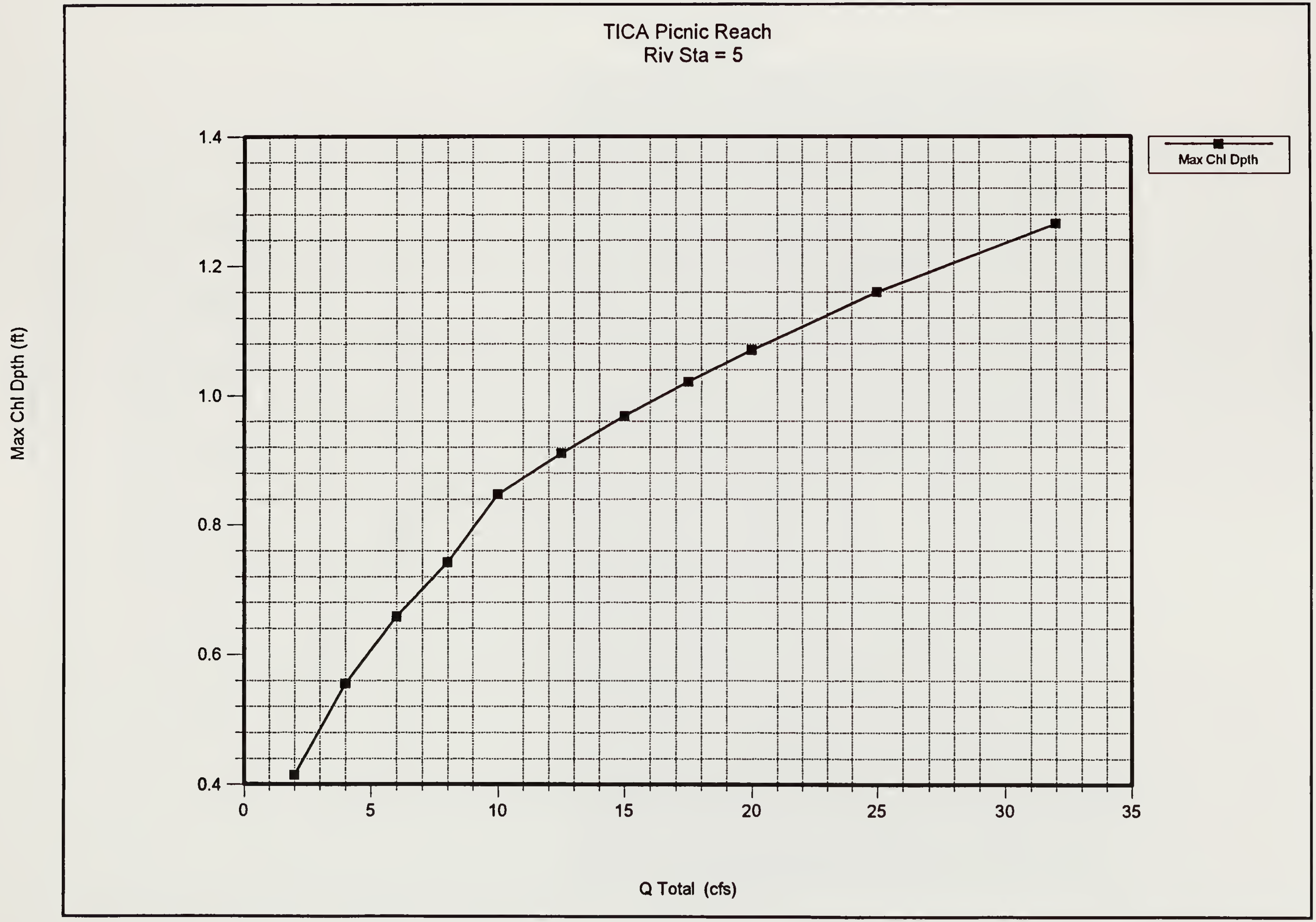
Picnic Area Reach
Cross Section 5



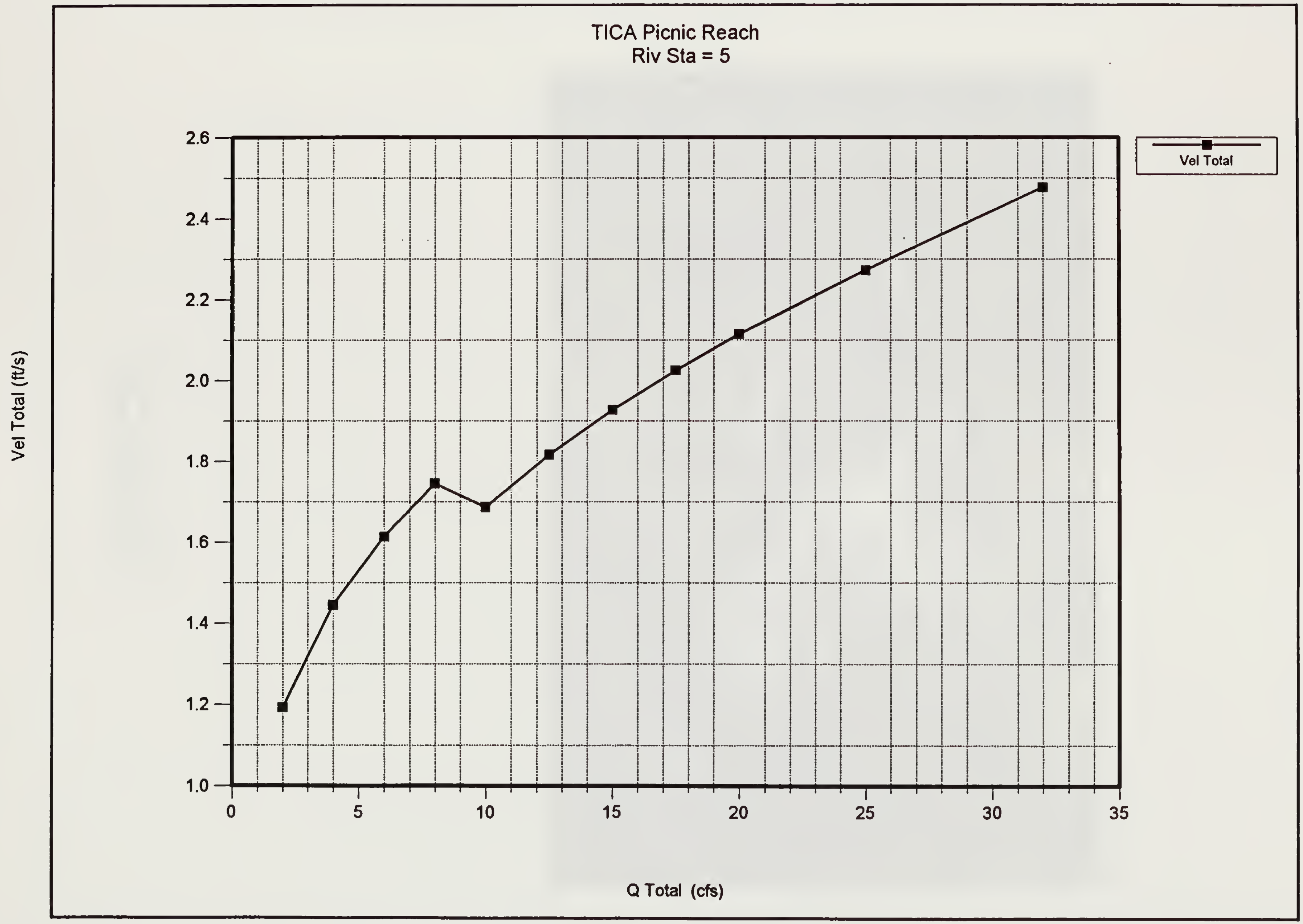
TICA Picnic Reach
Riv Sta = 5
.09
.095
.09
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
Elevation (ft)
92
91
90
89
88
87
86
0
5
10
15
20
25
30
35
Station (ft)
20
10
4



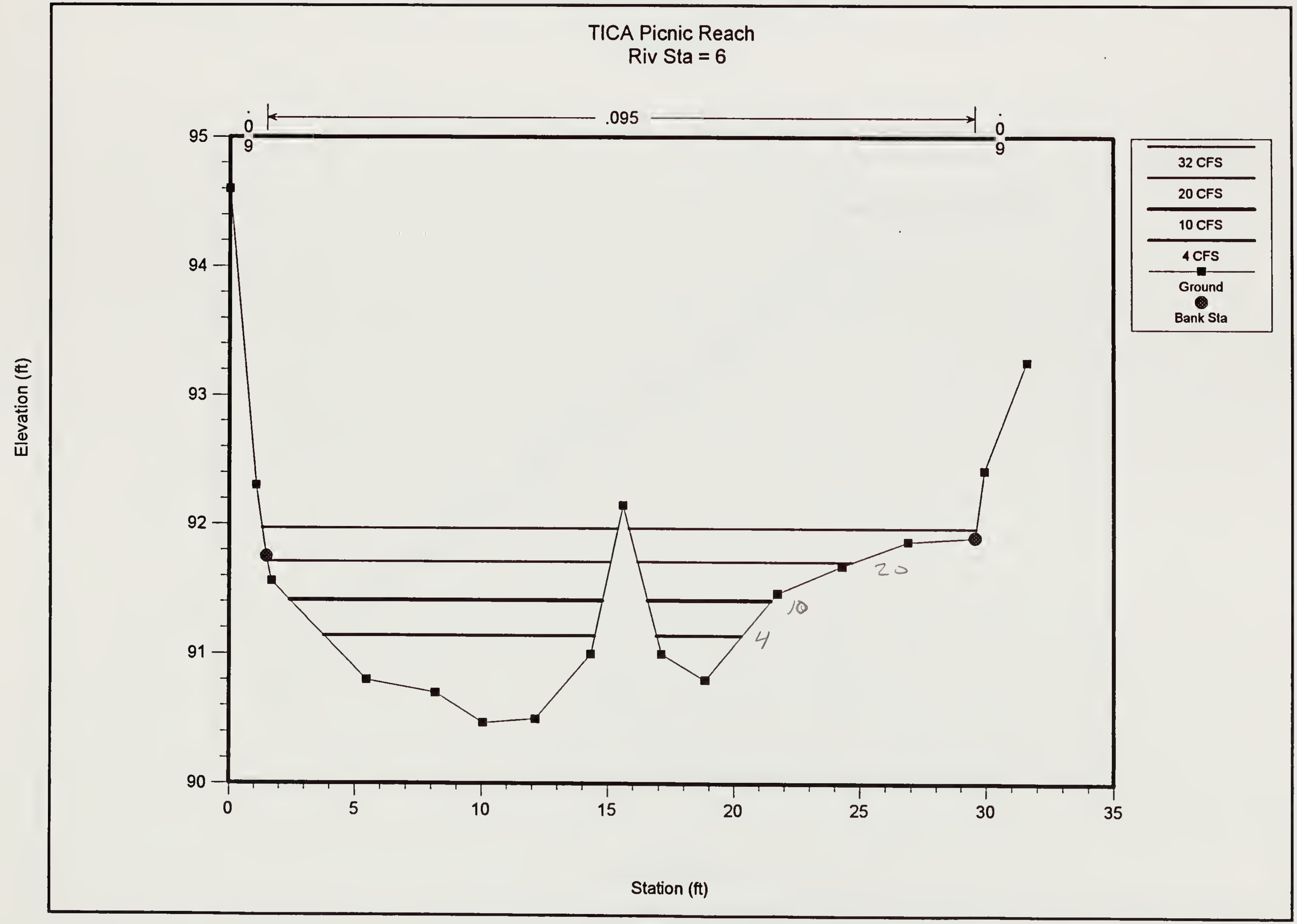
TICA Picnic Reach
Riv Sta = 5
Top Width
Top Width (ft)
Q Total (cfs)
20
18
16
14
12
10
8
6
0
5
10
15
20
25
30
35



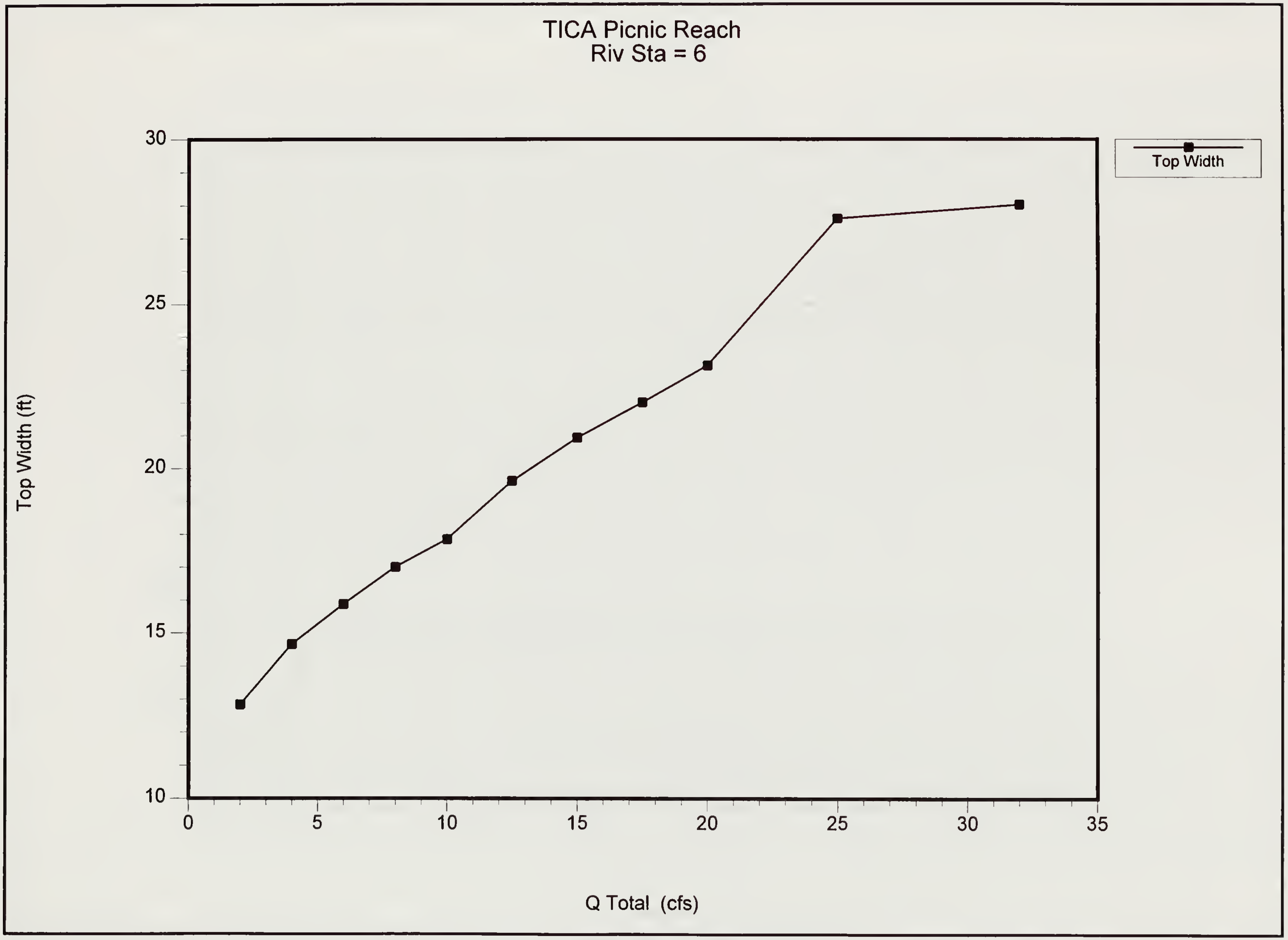
TICA Picnic Reach
Riv Sta = 5
Max Chl Dpth
Max Chl Dpth (ft)
1.4
1.2
1.0
0.8
0.6
0.4
0
5
10
15
20
25
30
35
Q Total (cfs)


TICA Picnic Reach
Riv Sta = 5
Vel Total (ft/s)
Q Total (cfs)
Vel Total
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0
5
10
15
20
25
30
35

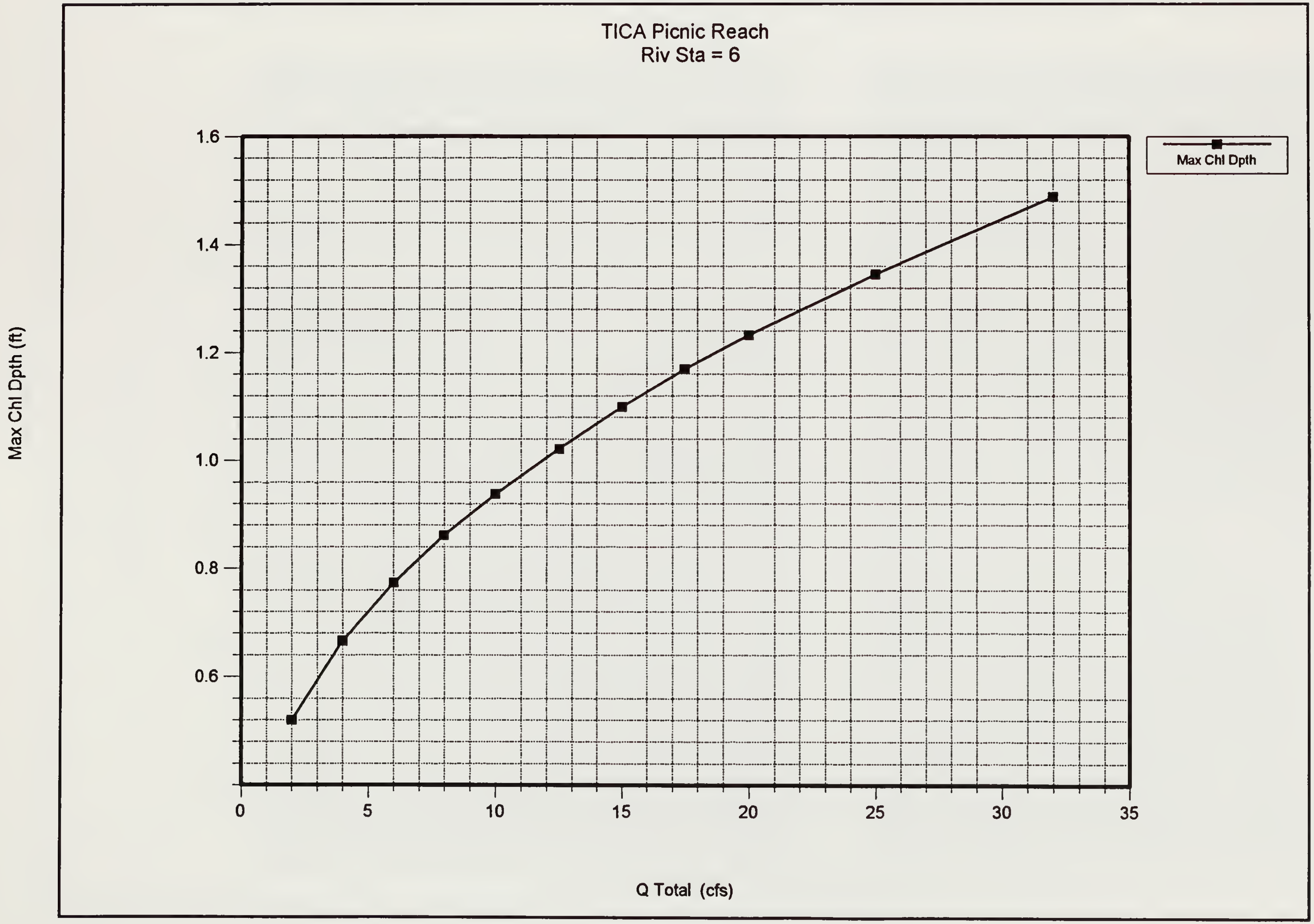
Picnic Area Reach
Cross Section 6



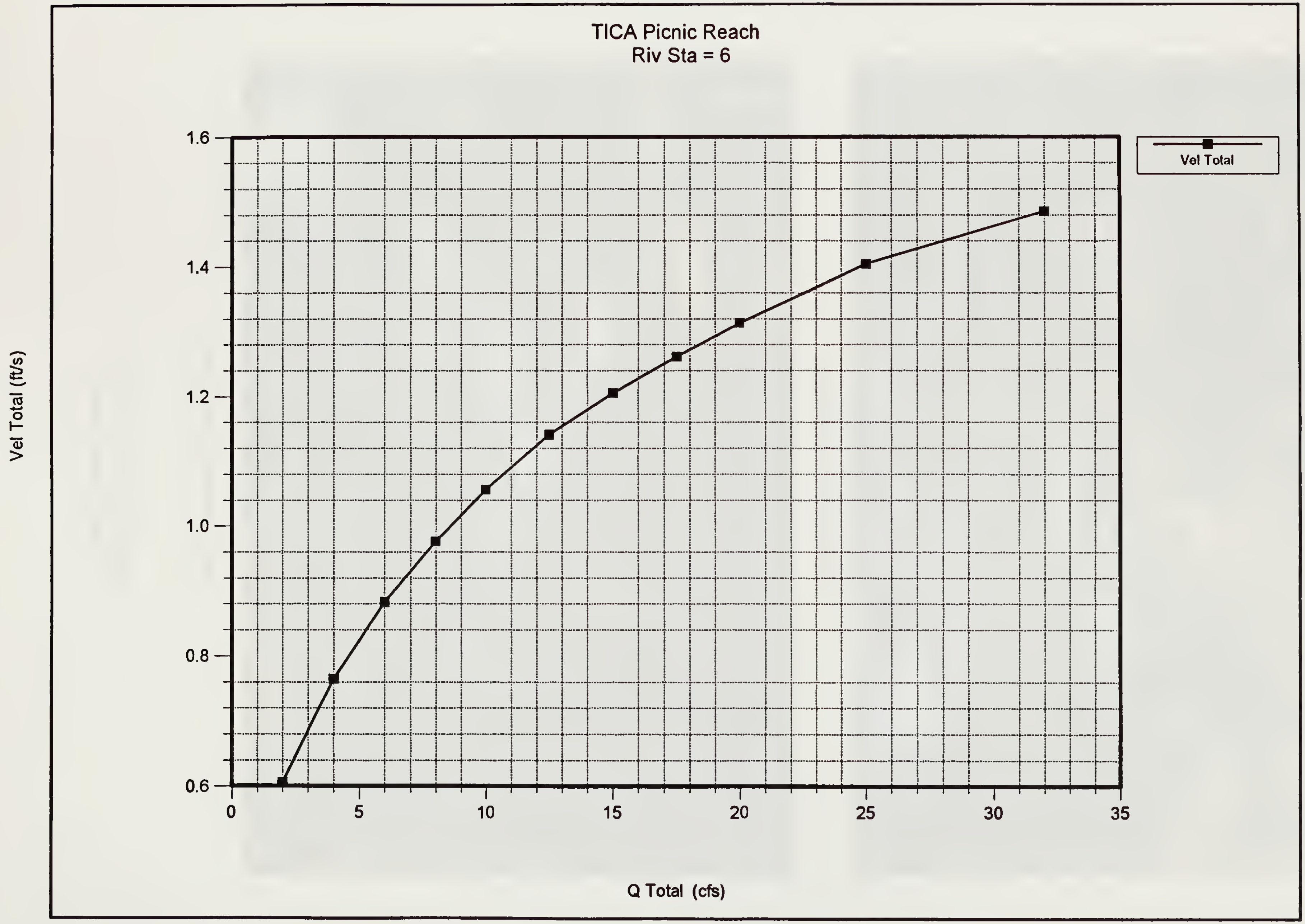
TICA Picnic Reach
Riv Sta = 6
.095
0
9
0
9
95
94
93
92
91
90
0
5
10
15
20
25
30
35
Elevation (ft)
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
20
10
4



TICA Picnic Reach
Riv Sta = 6
Top Width
Top Width (ft)
Q Total (cfs)
30
25
20
15
10
0
5
10
15
20
25
30
35



TICA Picnic Reach
Riv Sta = 6
Max Chl Dpth
Max Chl Dpth (ft)
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)

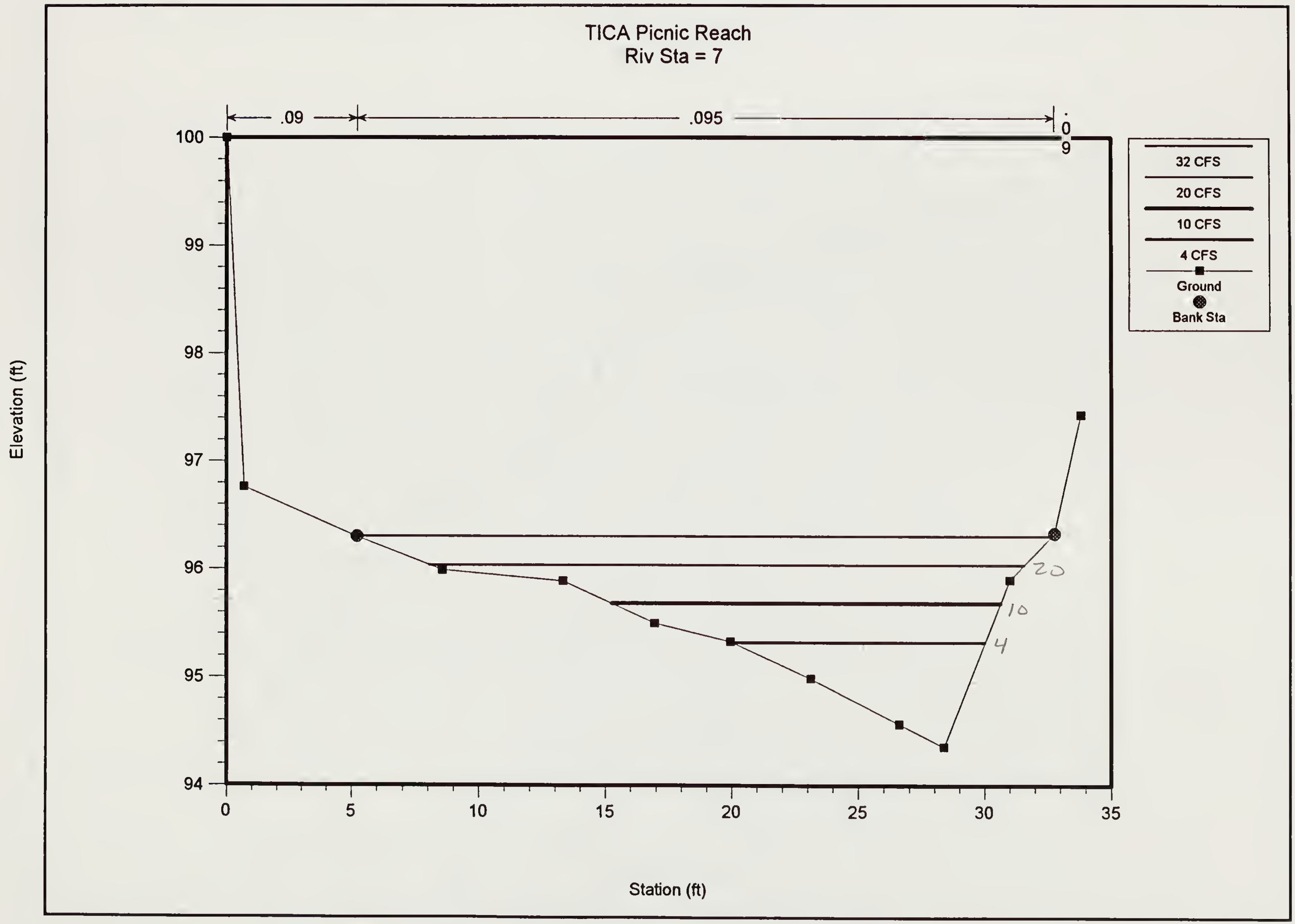


TICA Picnic Reach
Riv Sta = 6
Vel Total
Vel Total (ft/s)
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)

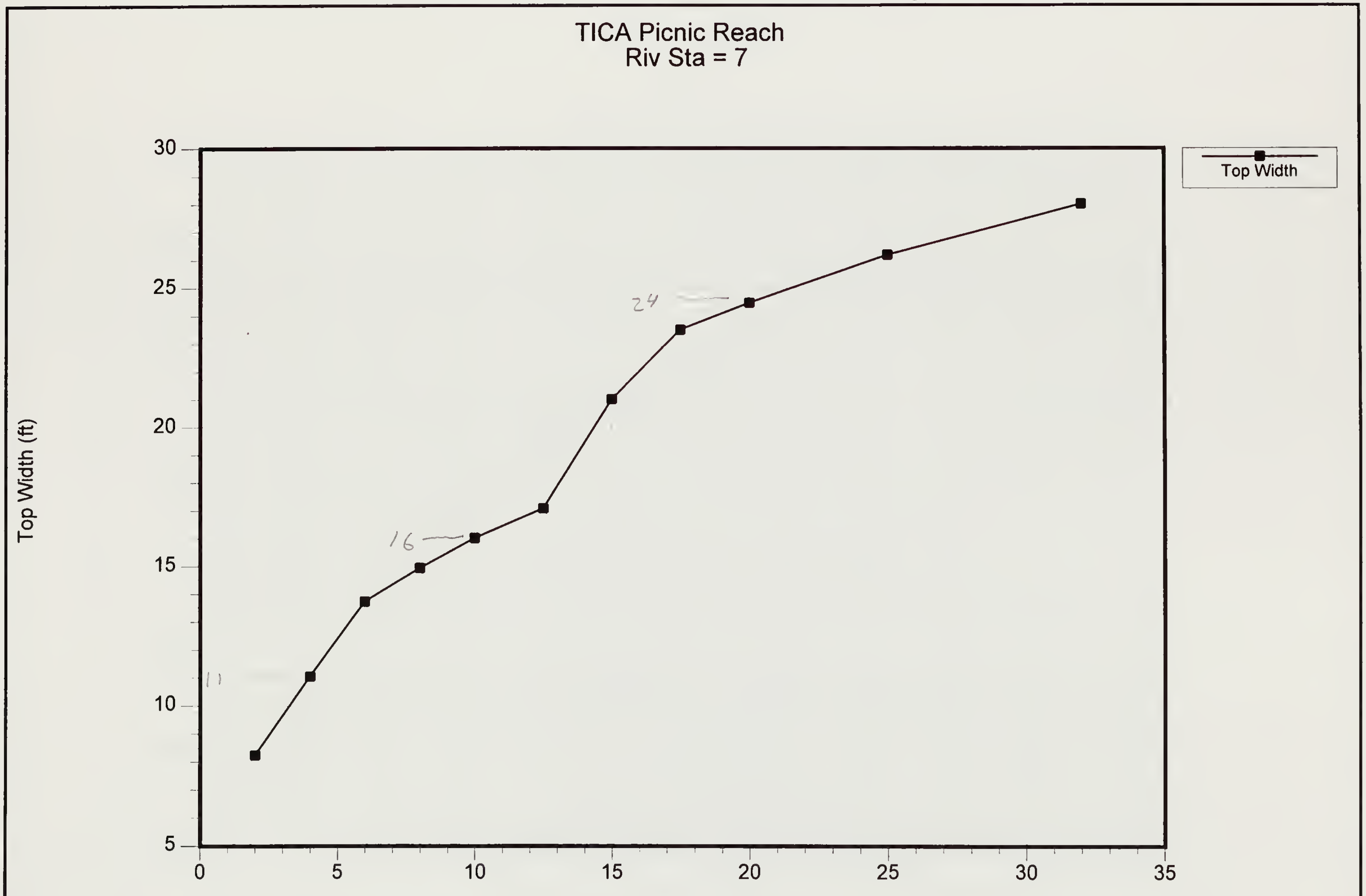
Looking Upstream

Looking Downstream

Picnic Area Reach
Cross Section 7

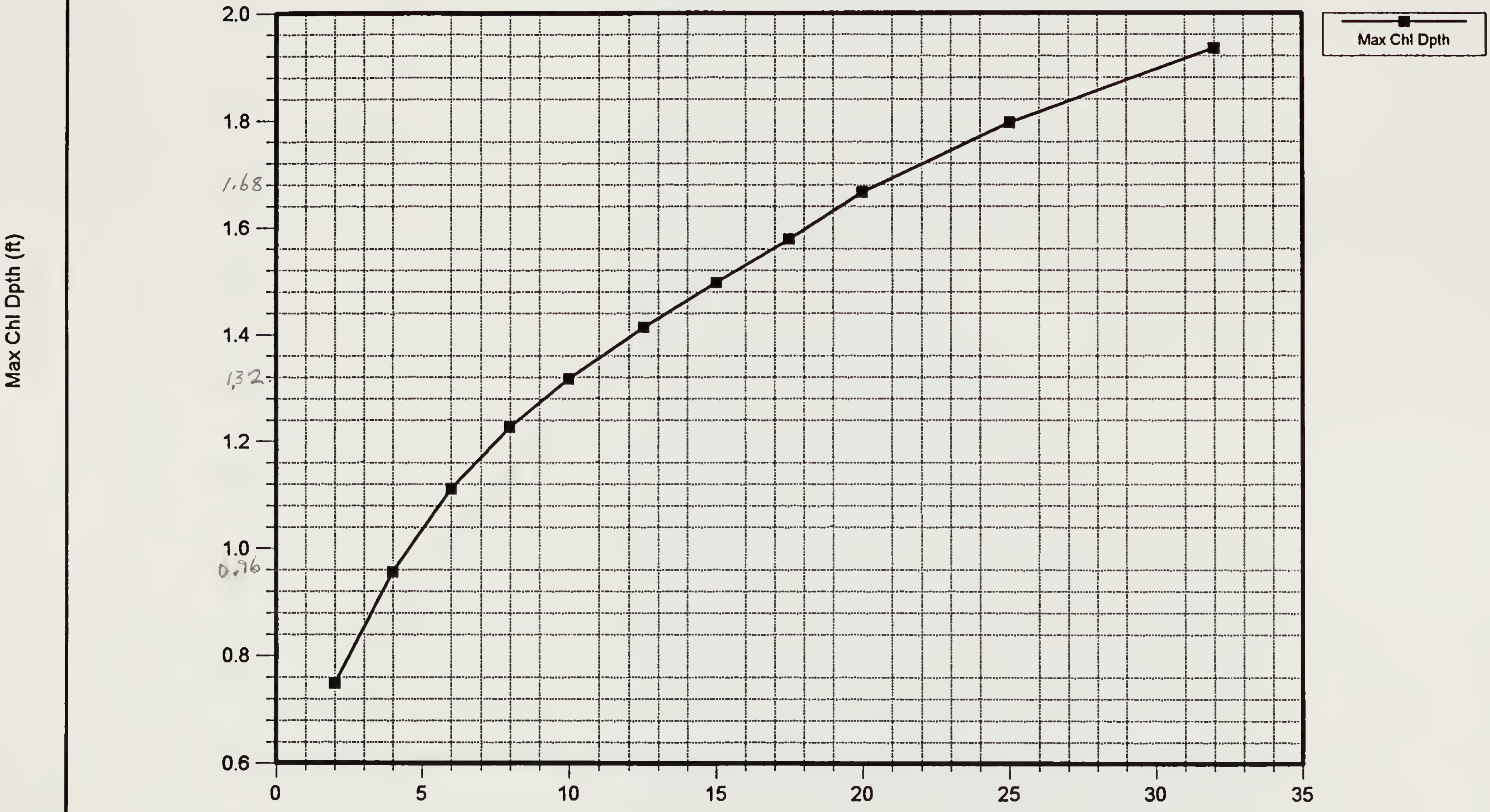


TICA Picnic Reach
Riv Sta = 7
.09
.095
.09
100
99
98
97
96
95
94
0
5
10
15
20
25
30
35
Elevation (ft)
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
20
10
4

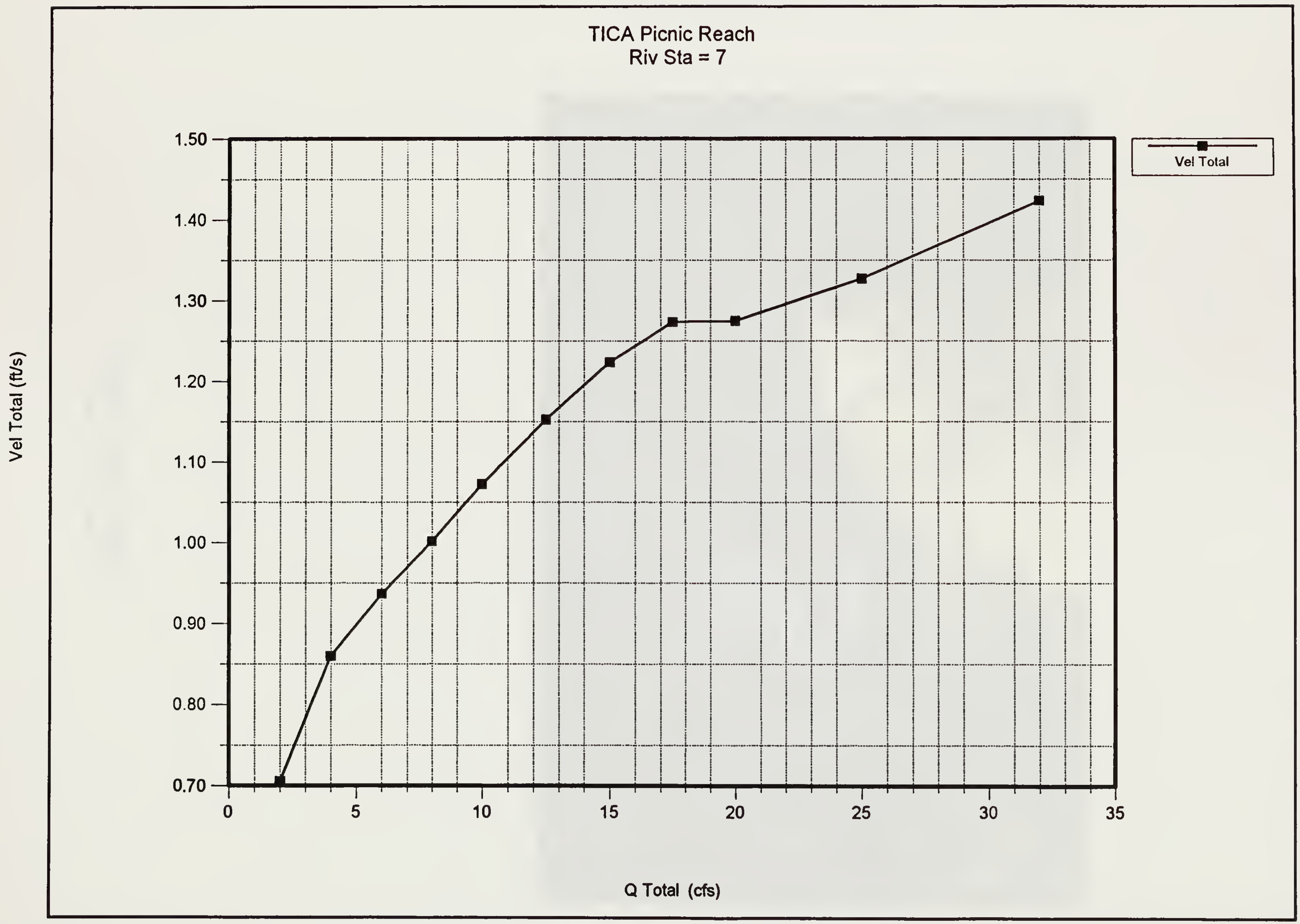


	ΔQ	Q_2/Q_1	ΔW		ΔW/ΔQ
4→10	1.5	2	5/11	.45	0.3
10→20	1.0	1/3	8/16	.50	0.5

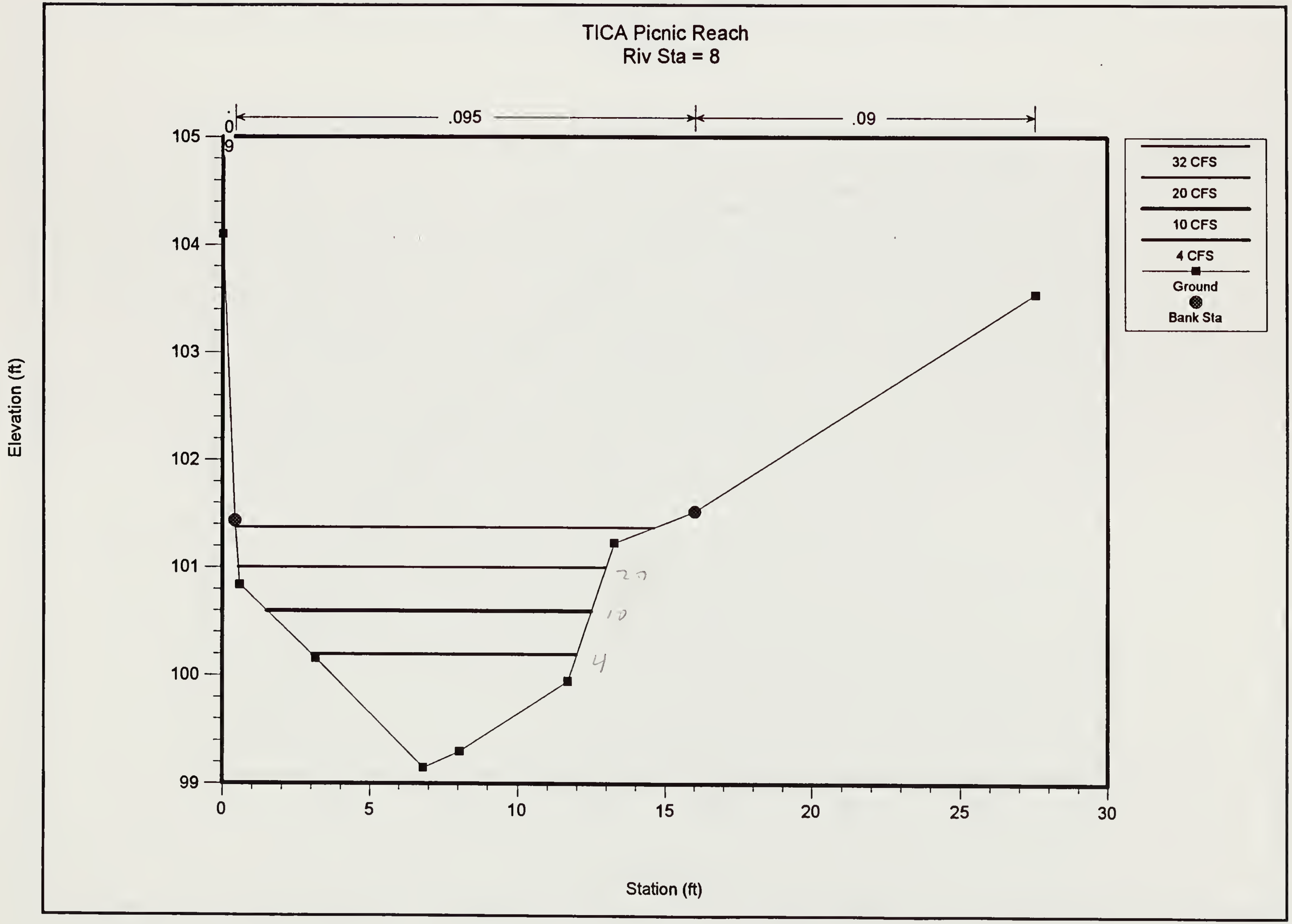
TICA Picnic Reach
Riv Sta = 7

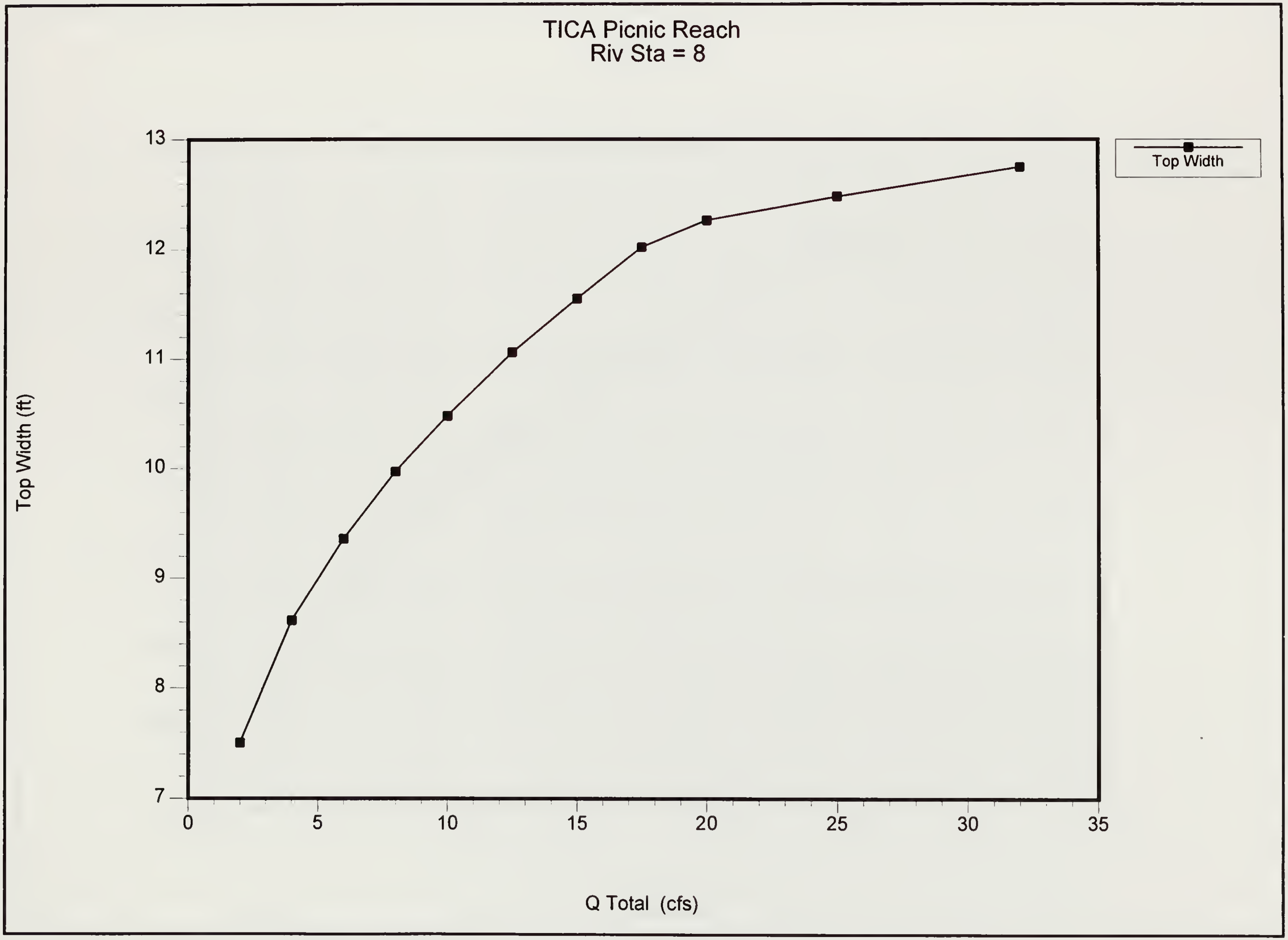


	ΔQ	Δw	Δw/ΔQ
4-10	1.5	0.38	0.25
10-20	1.0	0.27	0.27

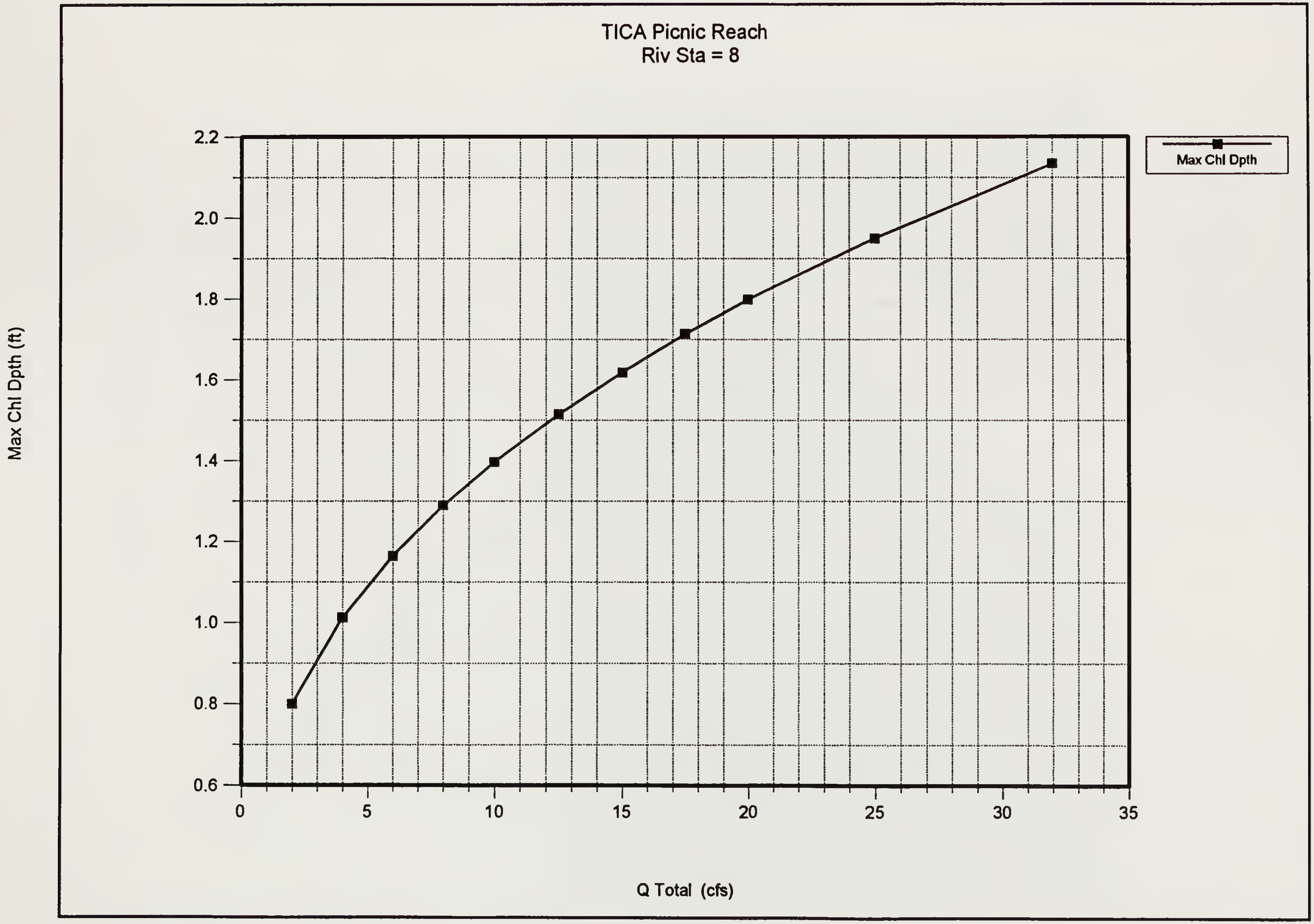

TICA Picnic Reach
Riv Sta = 7
Vel Total (ft/s)
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0
5
10
15
20
25
30
35
Q Total (cfs)
Vel Total

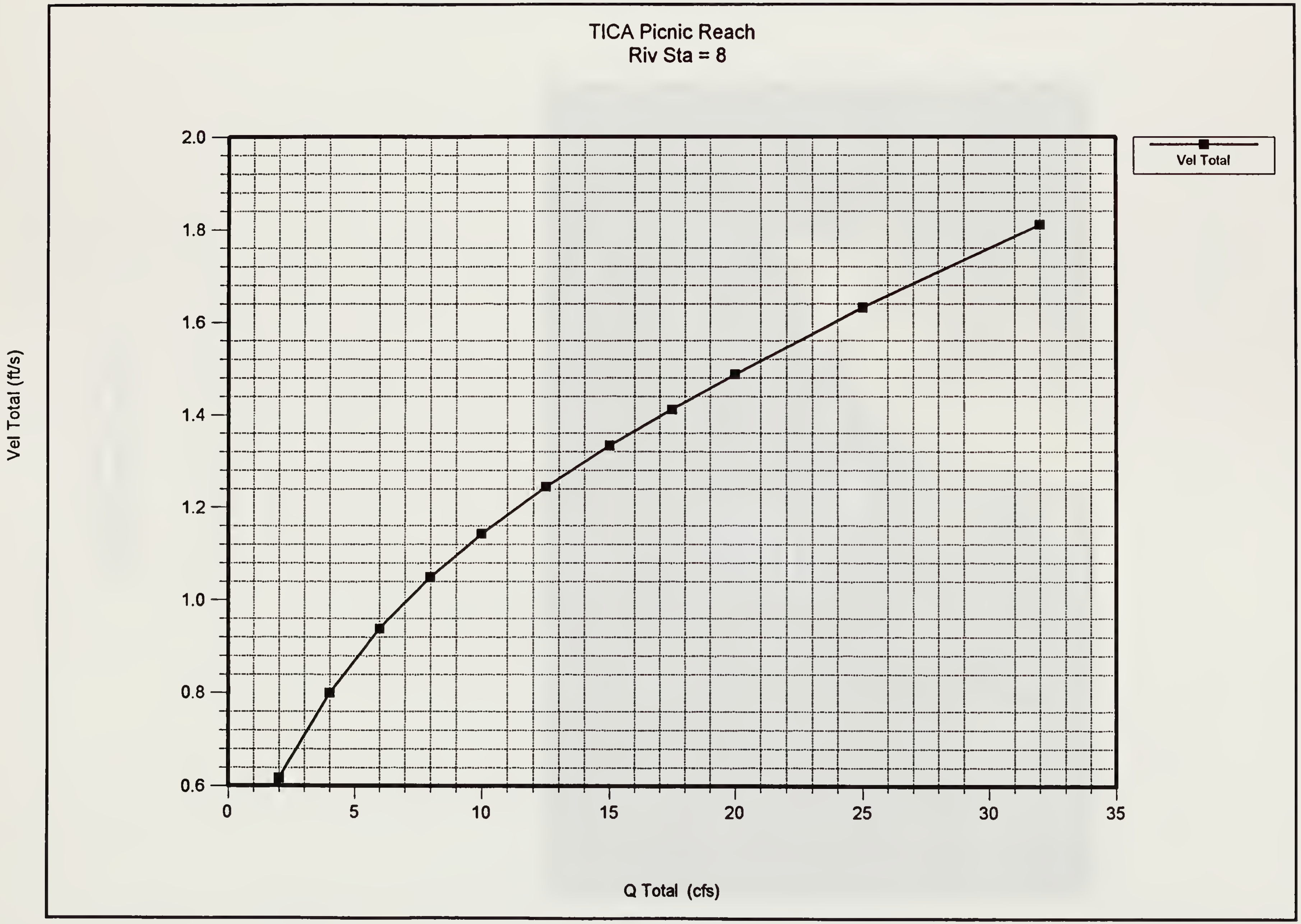
Picnic Area Reach
Cross Section 8


TICA Picnic Reach
Riv Sta = 8
.095
.09
0
.9
Elevation (ft)
105
104
103
102
101
100
99
Station (ft)
0
5
10
15
20
25
30
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
20
10
4

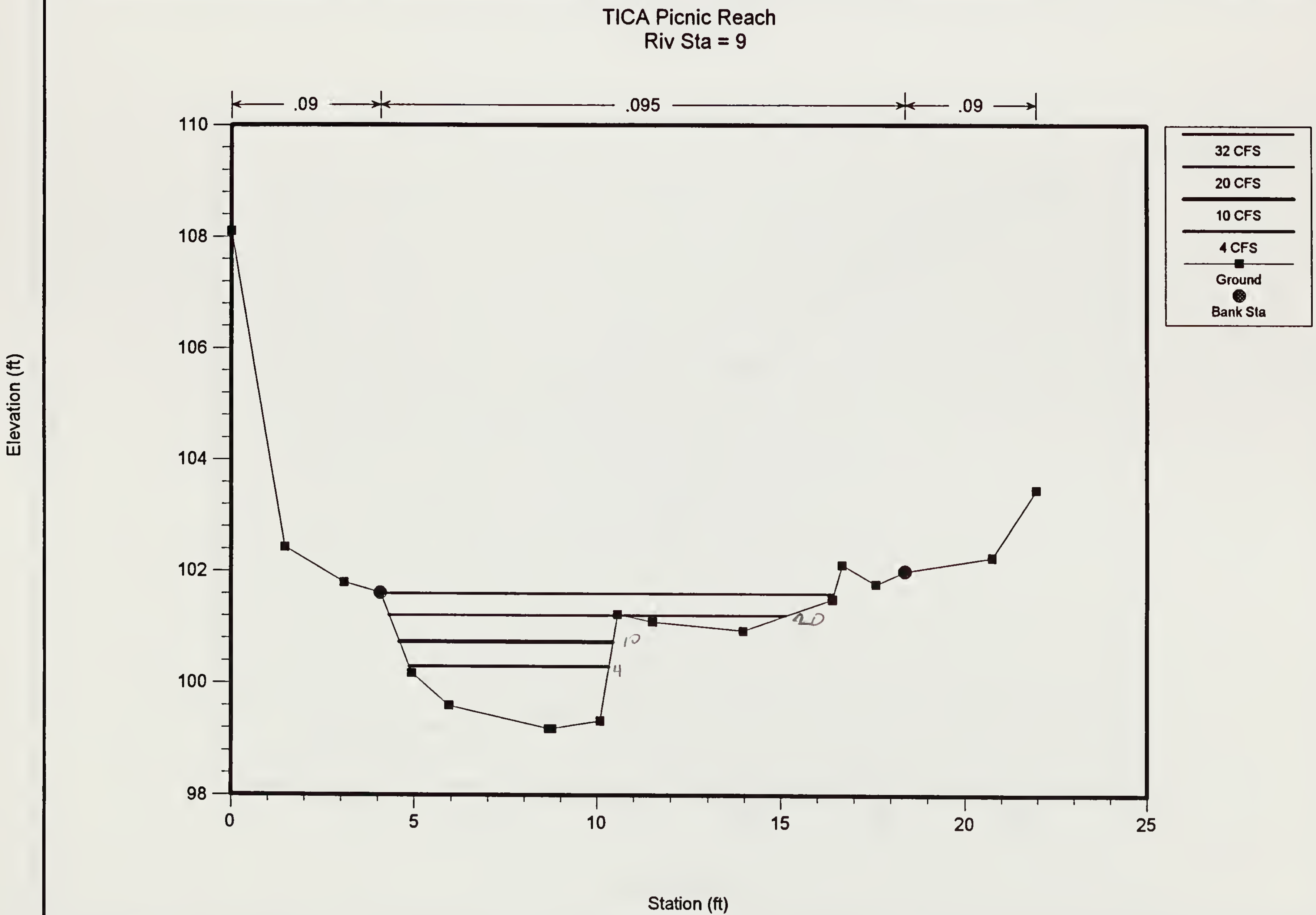


TICA Picnic Reach
Riv Sta = 8
Top Width
Top Width (ft)
Q Total (cfs)
13
12
11
10
9
8
7
0
5
10
15
20
25
30
35

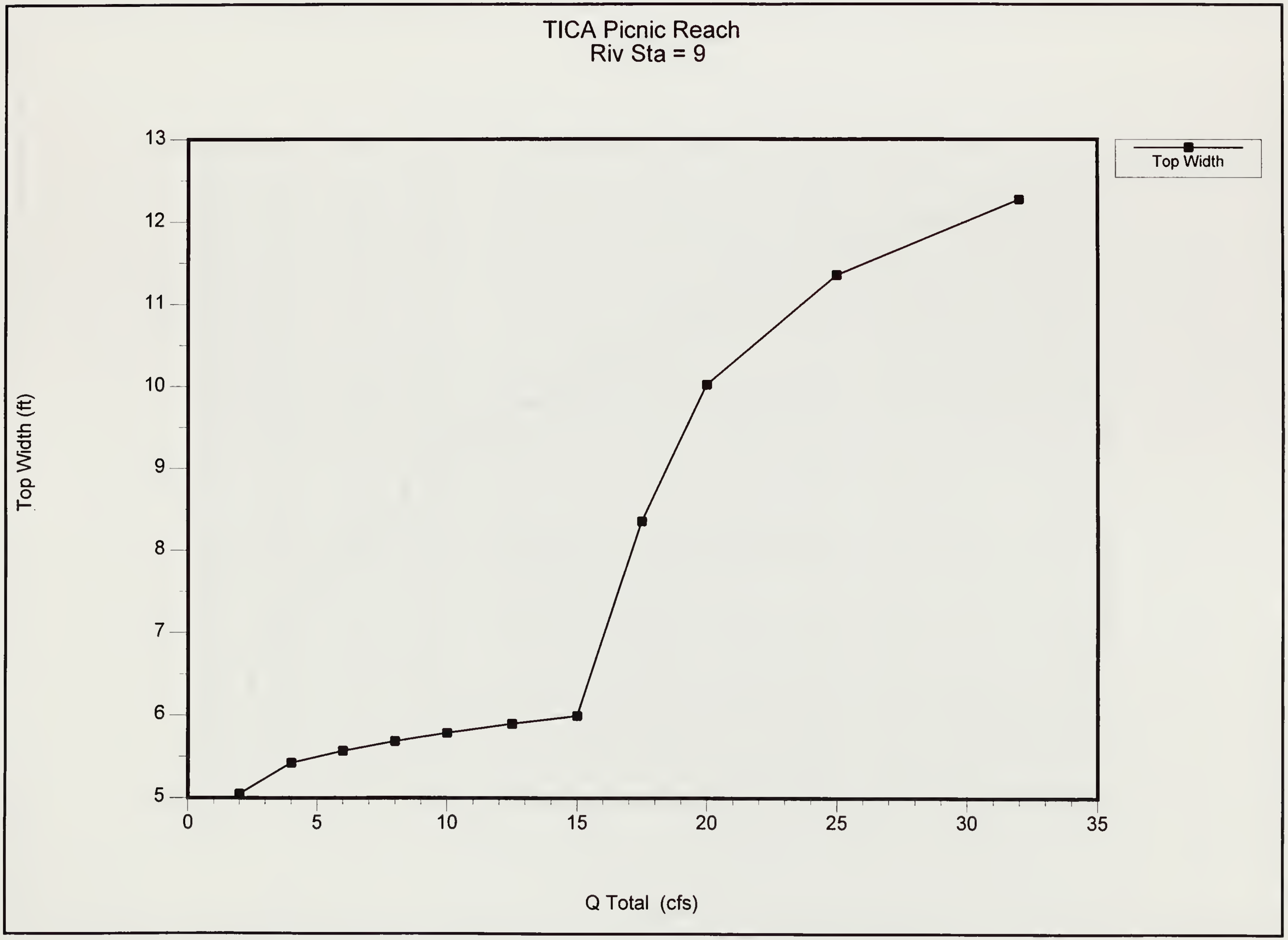

TICA Picnic Reach
Riv Sta = 8
Max Chl Dpth
Max Chl Dpth (ft)
Q Total (cfs)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35

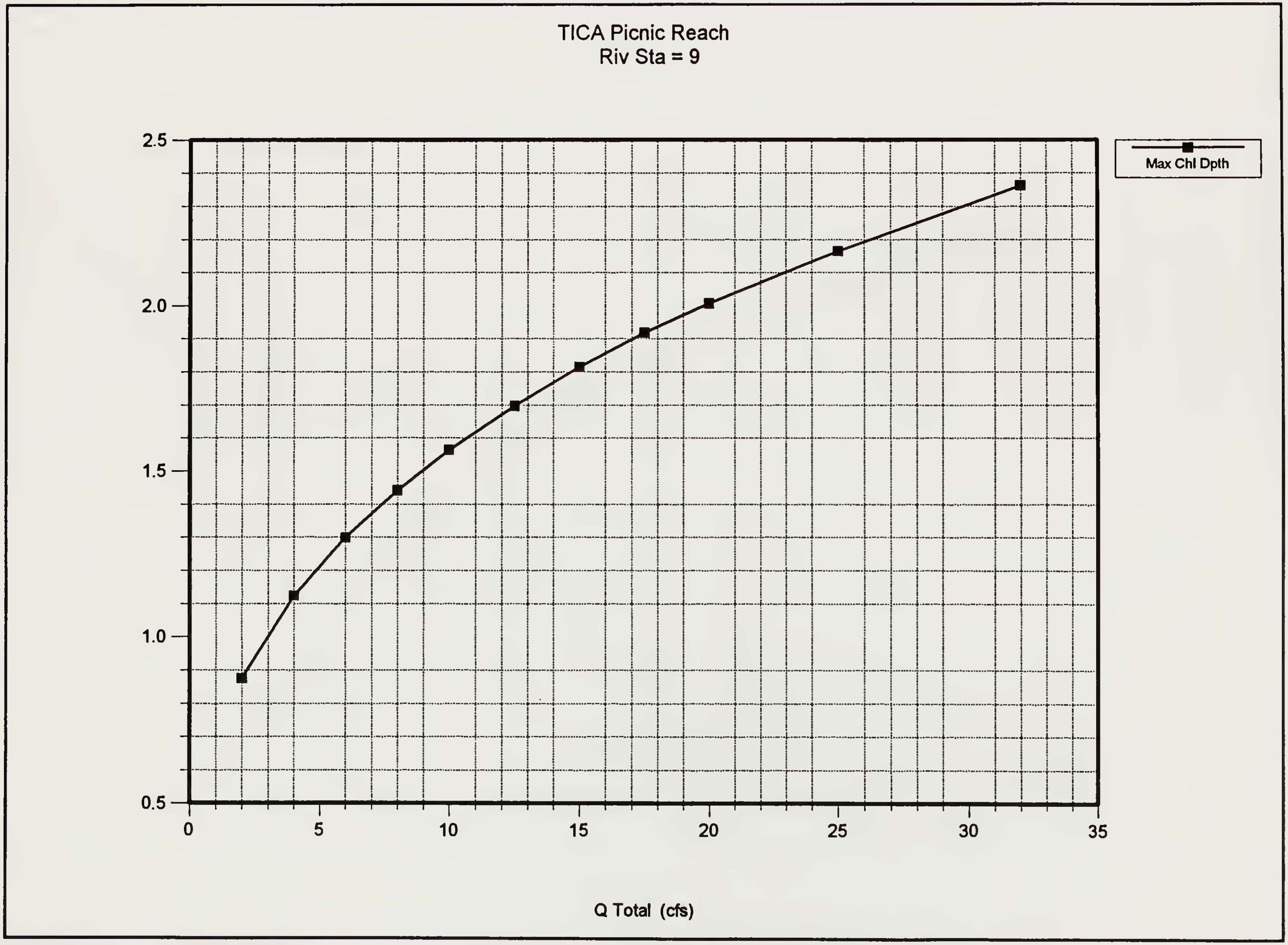

TICA Picnic Reach
Riv Sta = 8
Vel Total
Vel Total (ft/s)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)

Picnic Area Reach
Cross Section 9

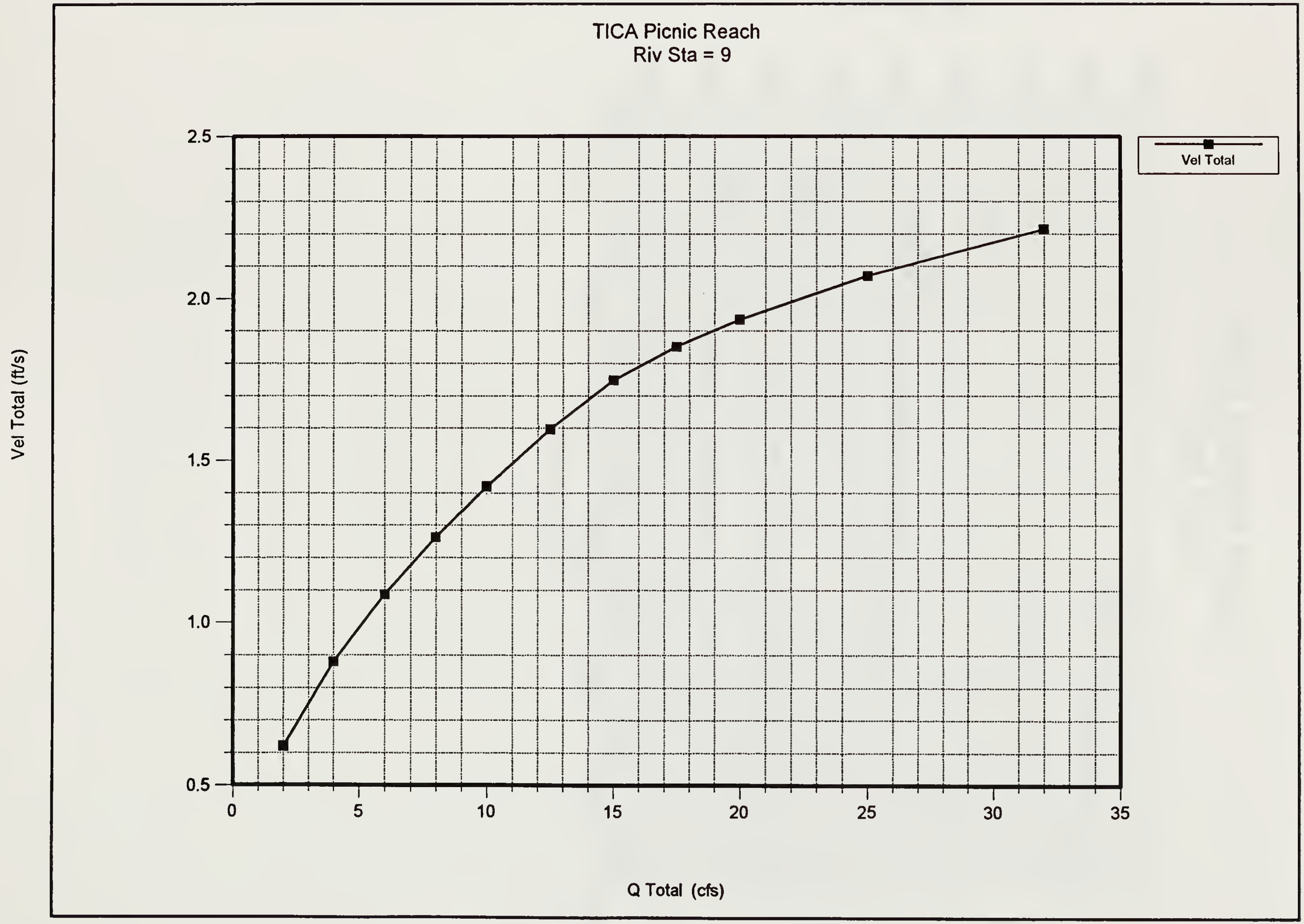


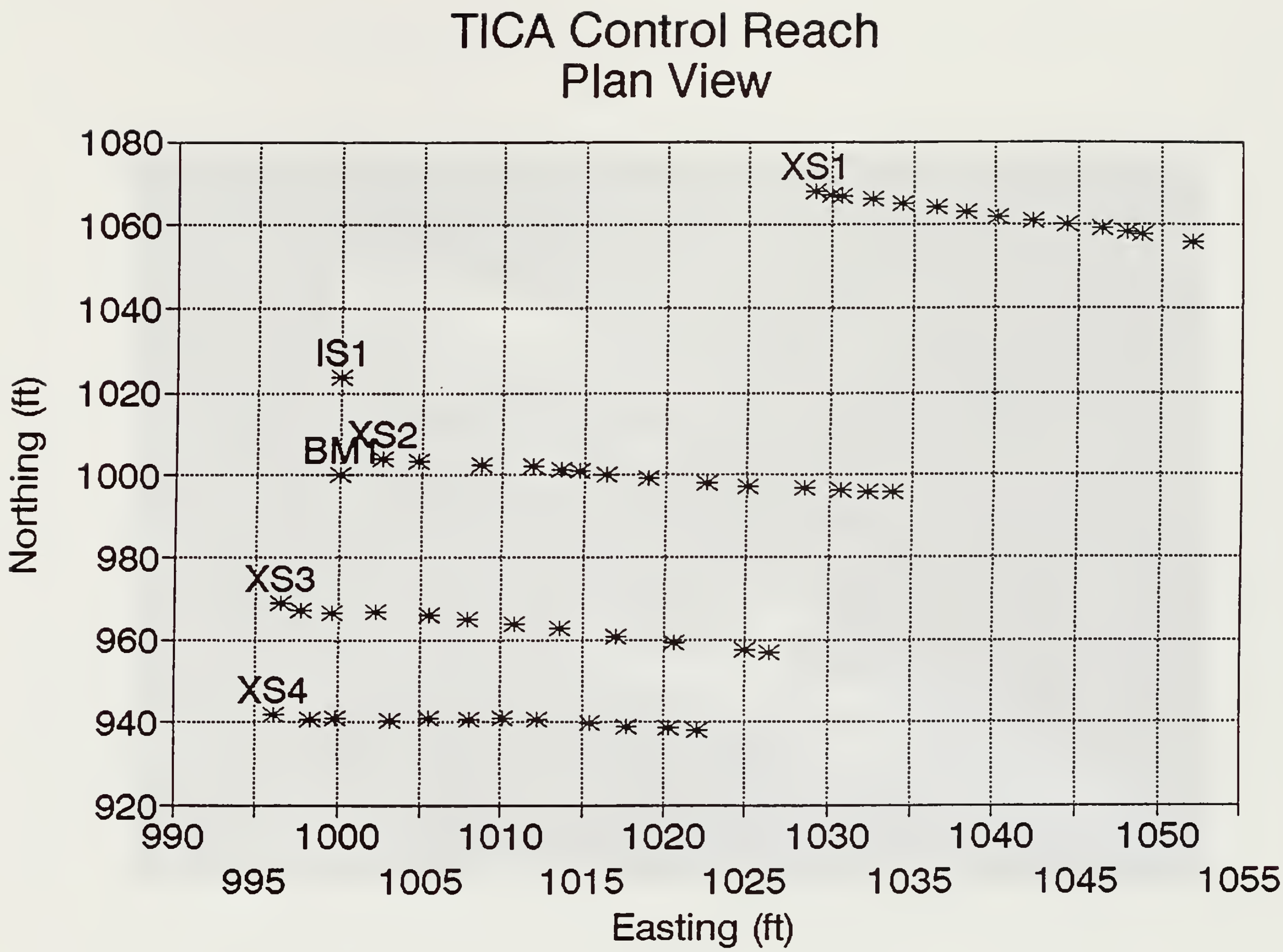
TICA Picnic Reach
Riv Sta = 9
.09
.095
.09
110
108
106
104
102
100
98
Elevation (ft)
0
5
10
15
20
25
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
20
10
4


TICA Picnic Reach
Riv Sta = 9
Top Width (ft)
Q Total (cfs)
Top Width
13
12
11
10
9
8
7
6
5
0
5
10
15
20
25
30
35



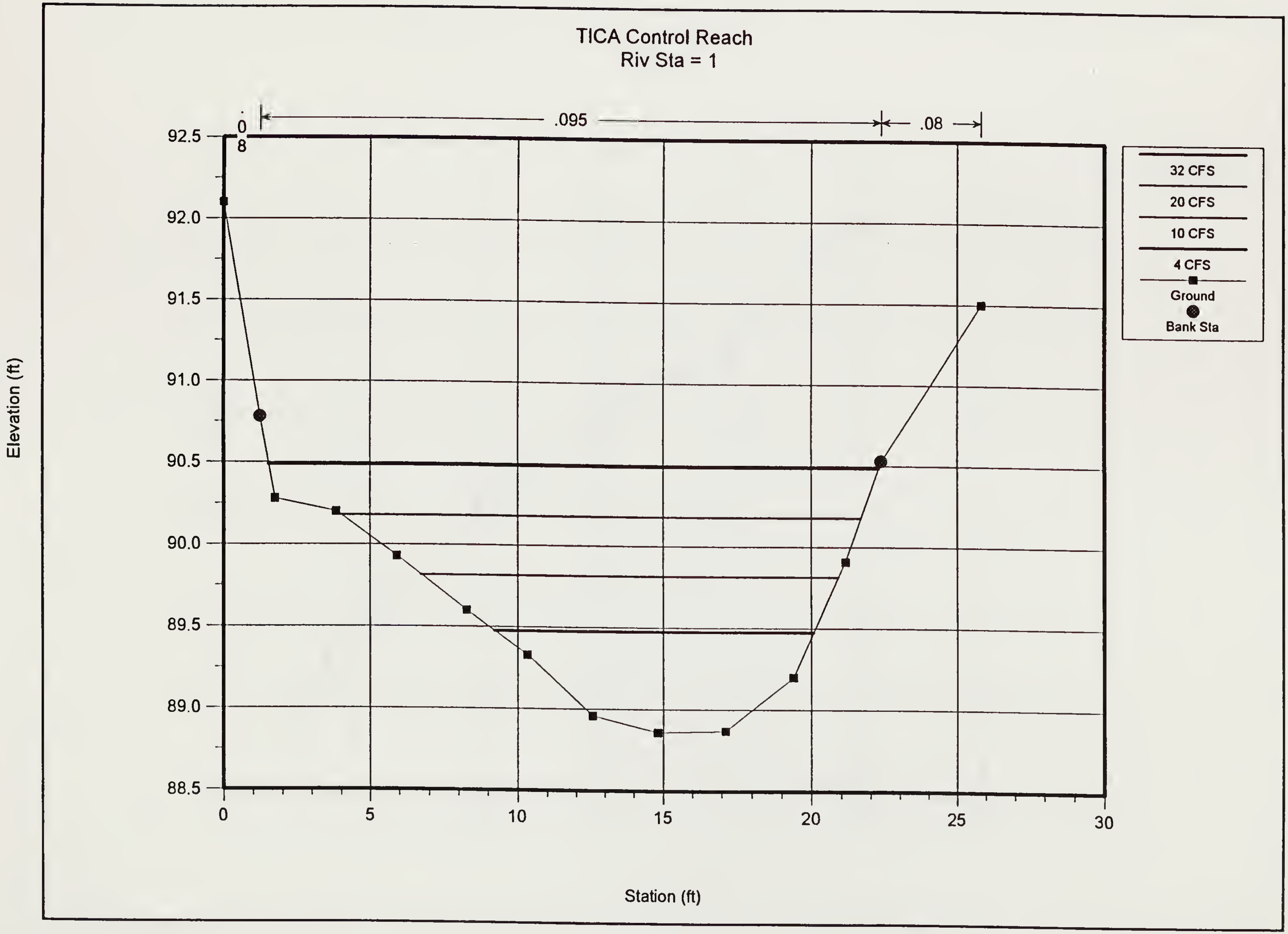
TICA Picnic Reach
Riv Sta = 9
Max Chl Dpth
Max Chl Dpth (ft)
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
25
30
35
Q Total (cfs)

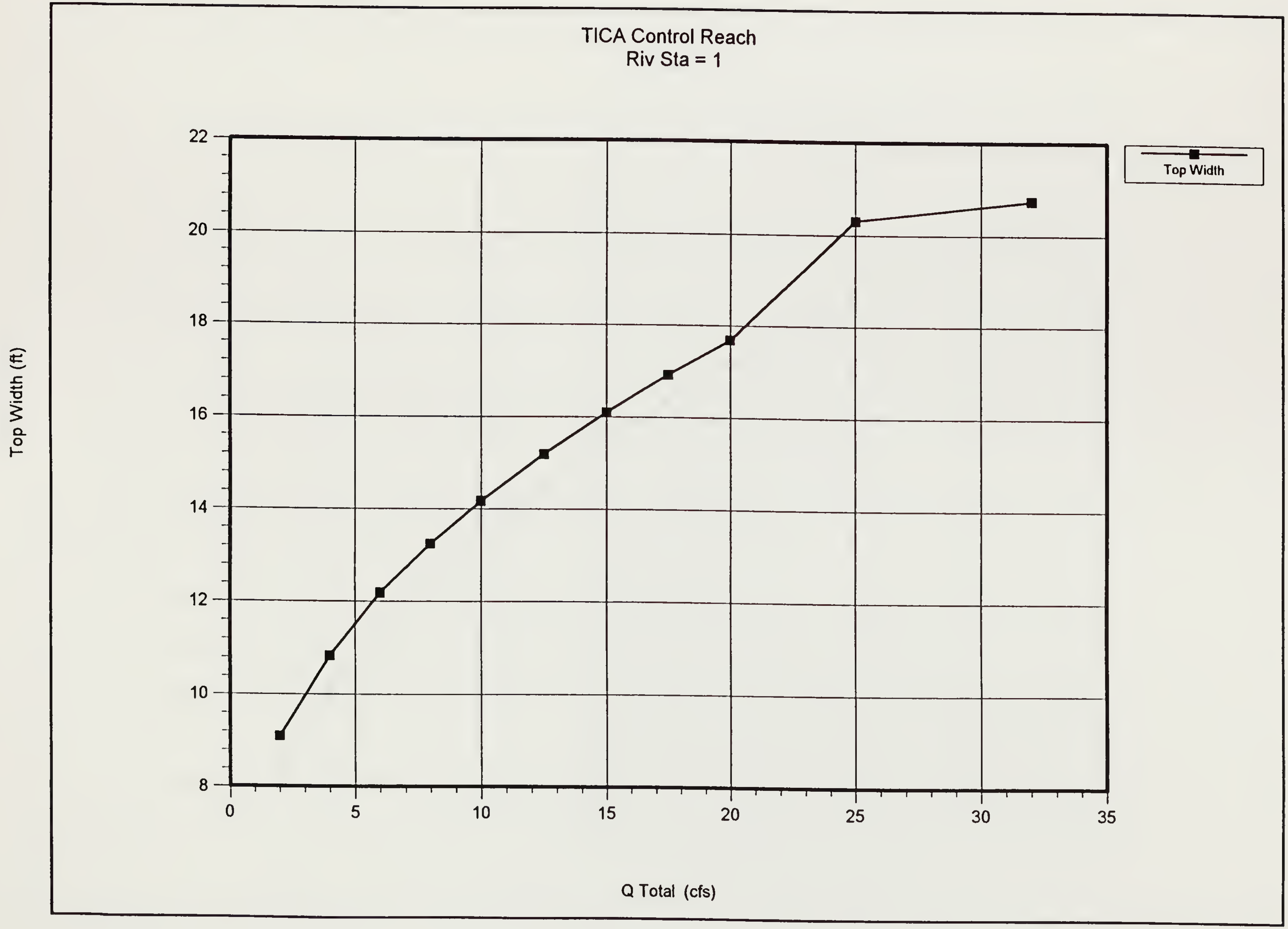

TICA Picnic Reach
Riv Sta = 9
Vel Total (ft/s)
Q Total (cfs)
Vel Total
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
25
30
35

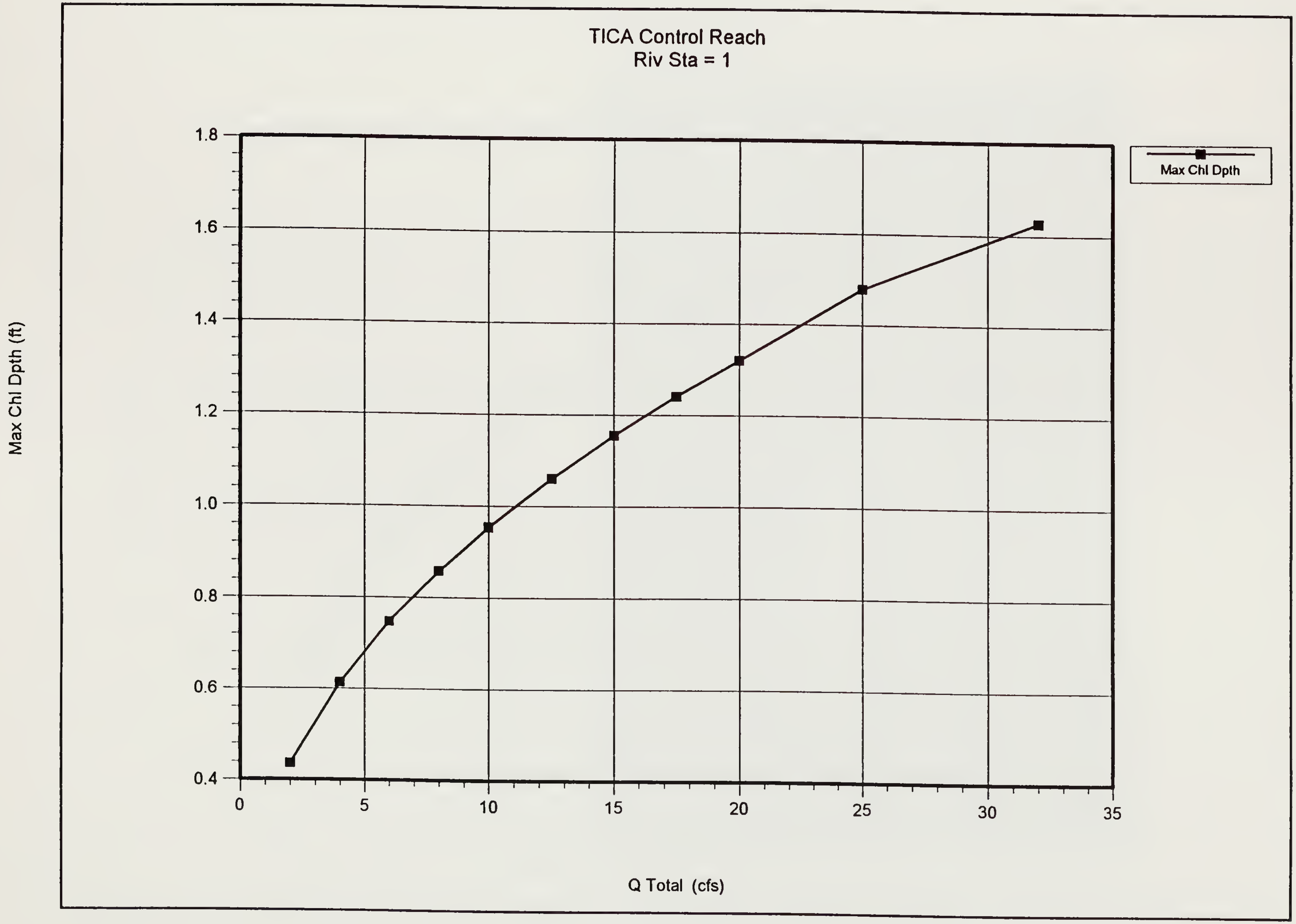


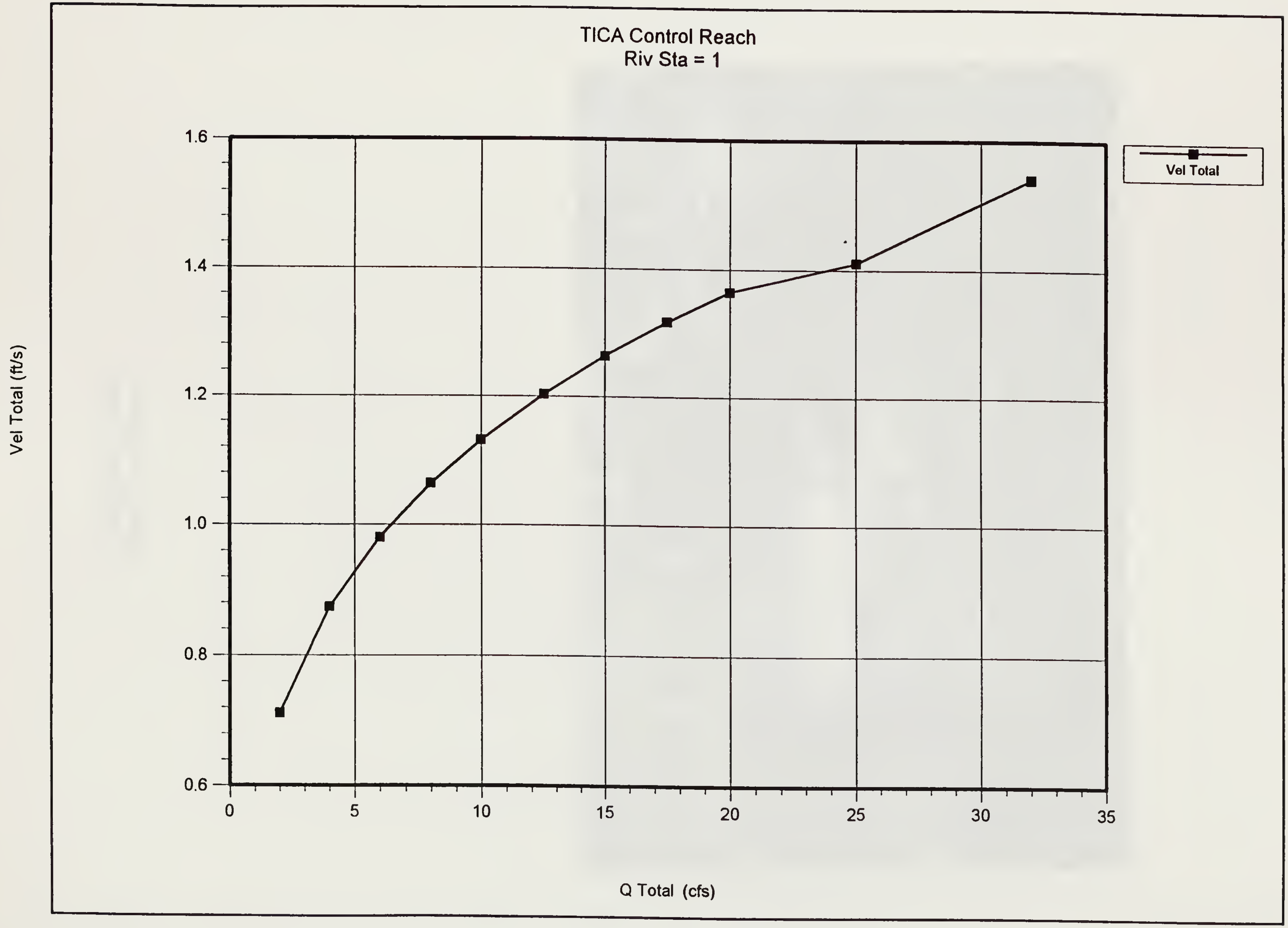
TICA Control Reach
Plan View
Northing (ft)
Easting (ft)
XS1
IS1
XS2
BM1
XS3
XS4
1080
1060
1040
1020
1000
980
960
940
920
990
995
1000
1005
1010
1015
1020
1025
1030
1035
1040
1045
1050
1055

Control Reach
Cross Section 1

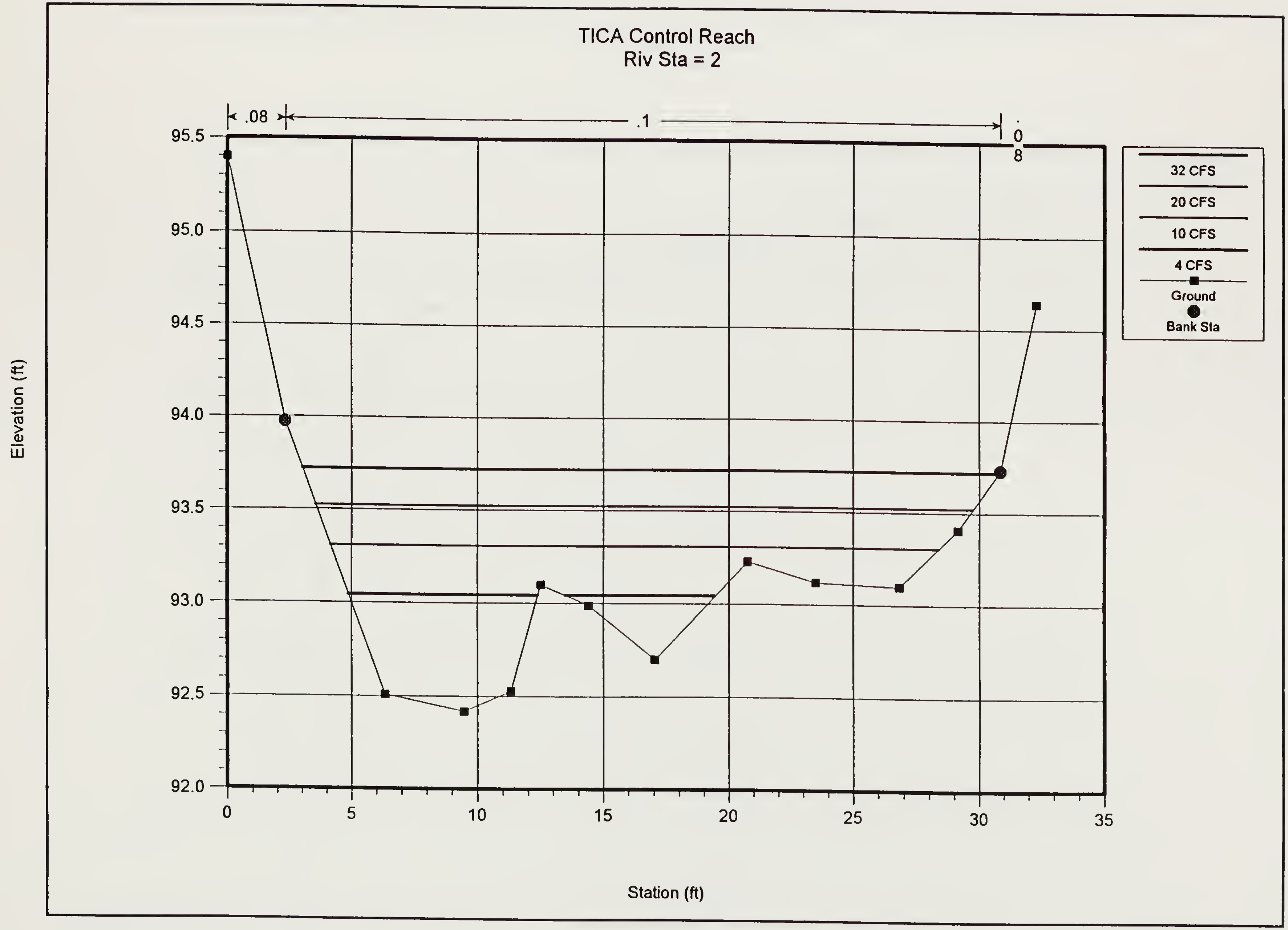

TICA Control Reach
Riv Sta = 1
.08
.095
.08
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
Elevation (ft)
Station (ft)
92.5
92.0
91.5
91.0
90.5
90.0
89.5
89.0
88.5
0
5
10
15
20
25
30

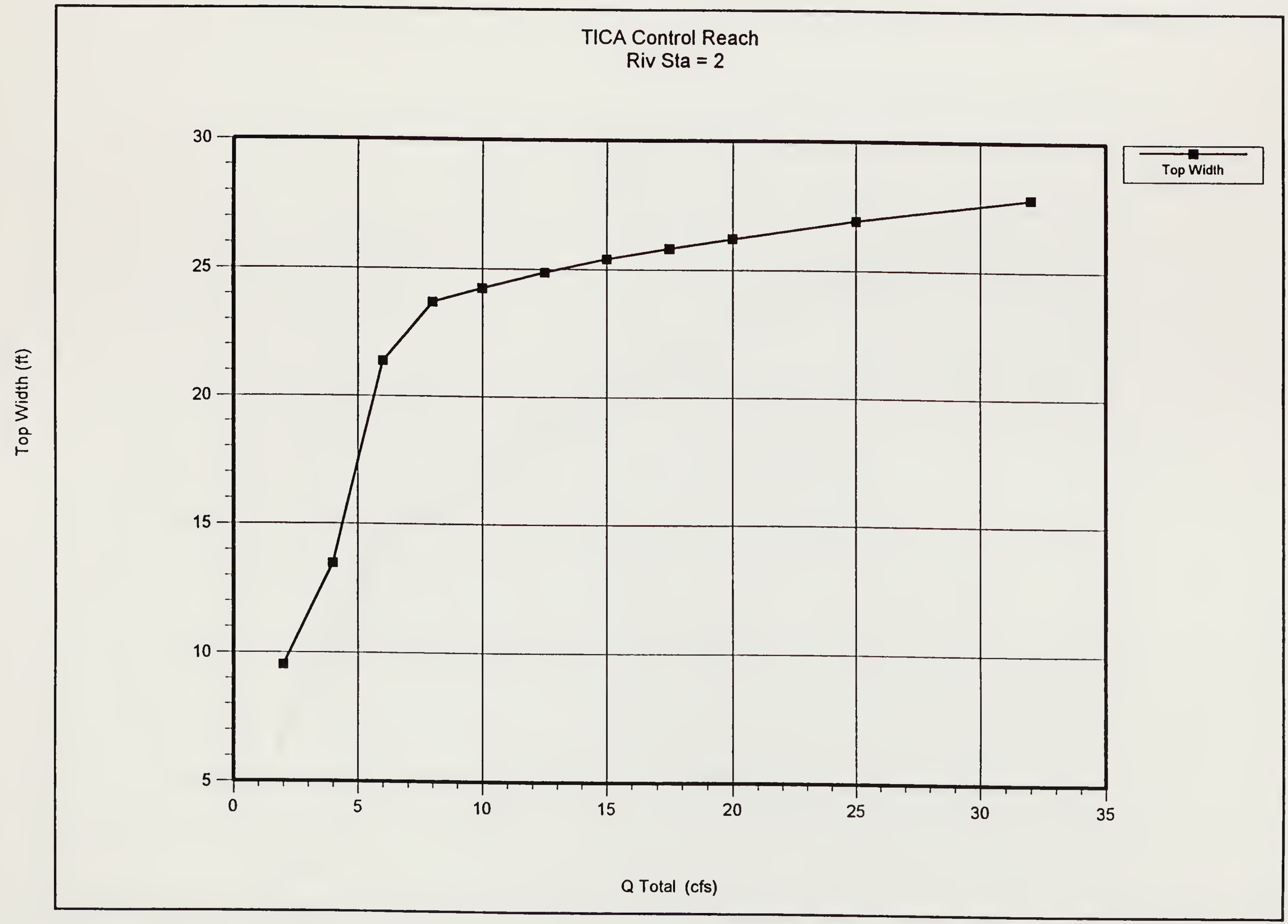

TICA Control Reach
Riv Sta = 1
Top Width
Top Width (ft)
Q Total (cfs)
22
20
18
16
14
12
10
8
0
5
10
15
20
25
30
35


TICA Control Reach
Riv Sta = 1
Max Chl Dpth (ft)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
5
10
15
20
25
30
35
Q Total (cfs)
Max Chl Dpth

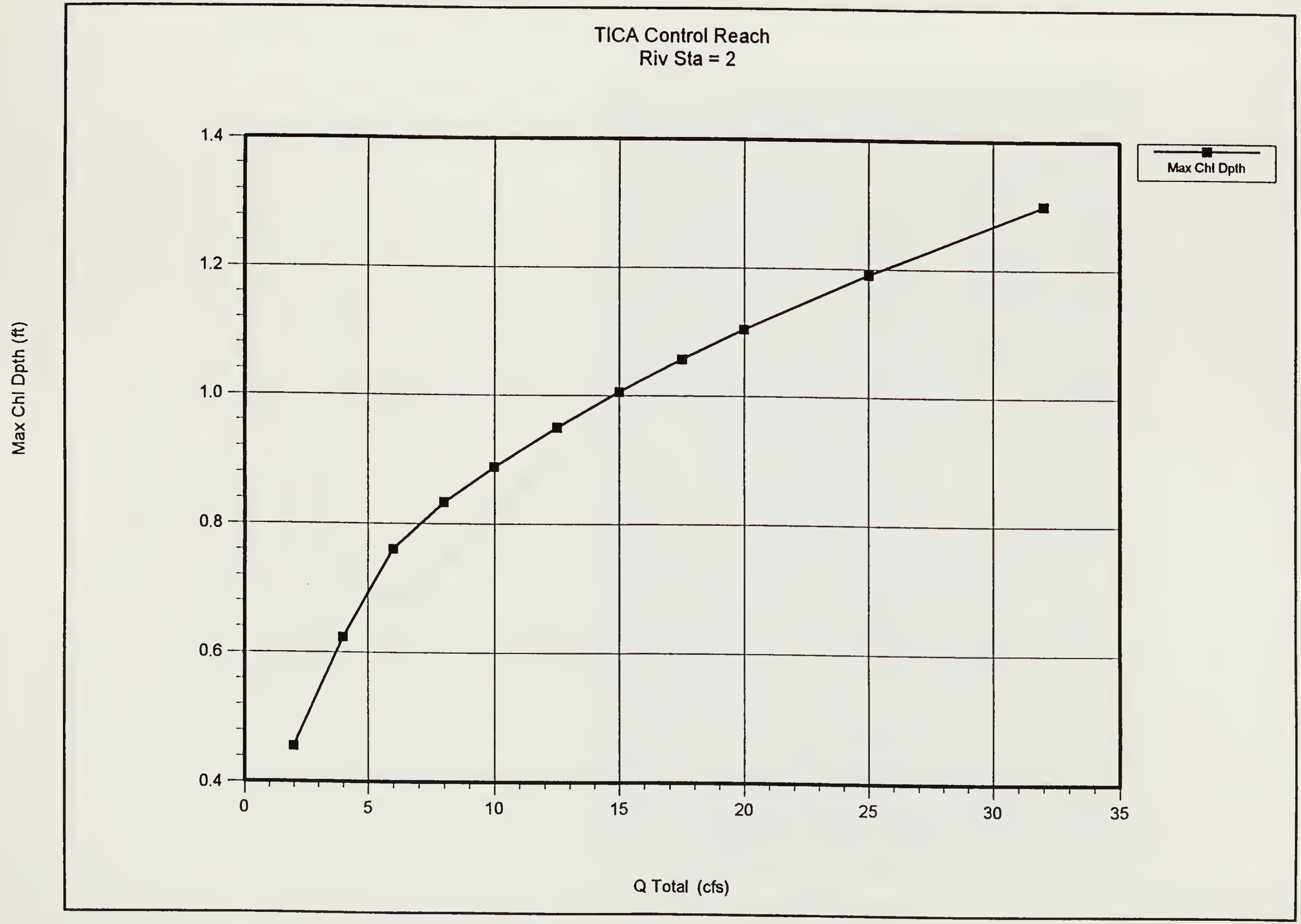

TICA Control Reach
Riv Sta = 1
Vel Total (ft/s)
Q Total (cfs)
Vel Total
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35

Control Reach
Cross Section 2

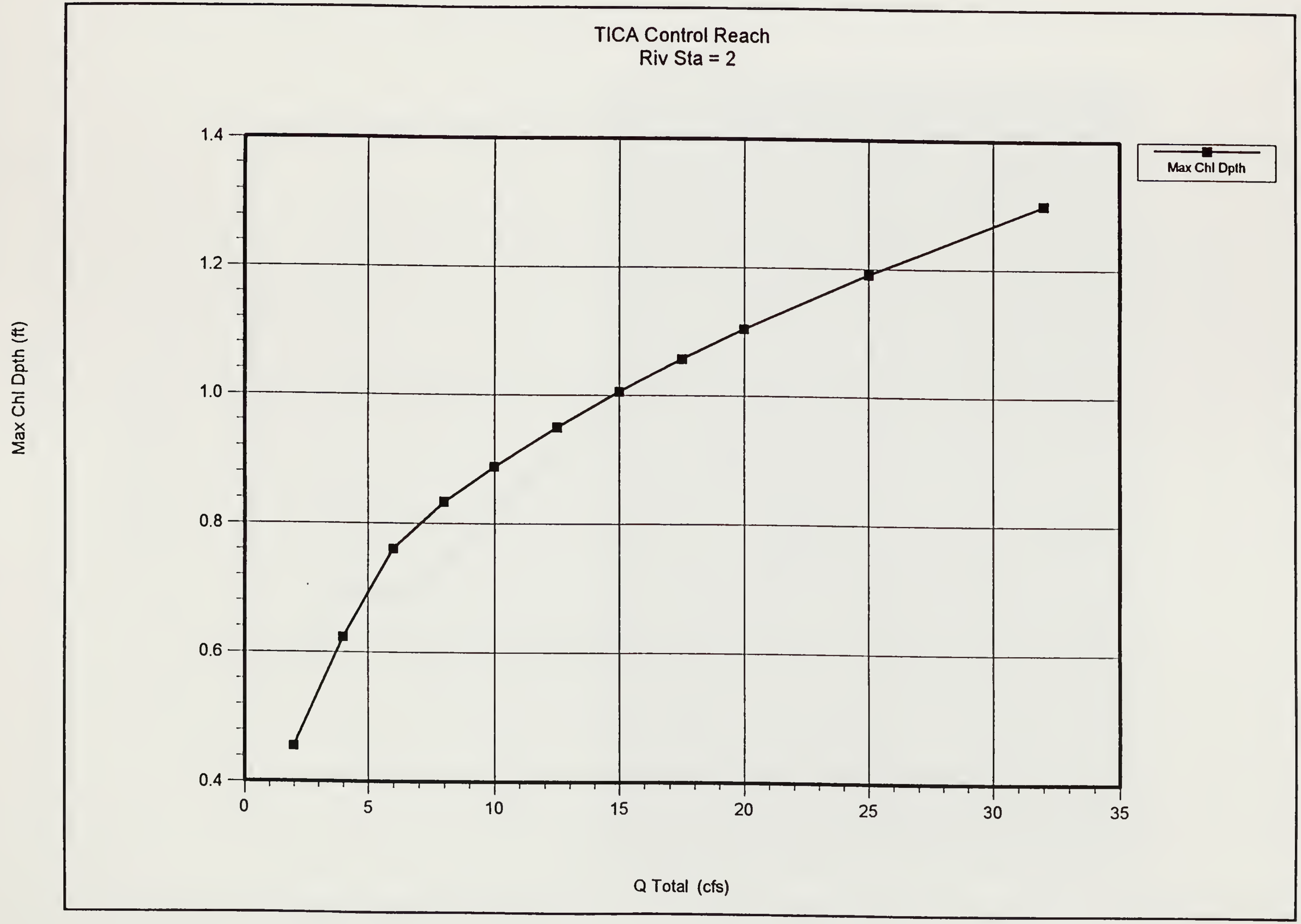

TICA Control Reach
Riv Sta = 2
.08
.1
.08
95.5
95.0
94.5
94.0
93.5
93.0
92.5
92.0
0
5
10
15
20
25
30
35
Elevation (ft)
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta



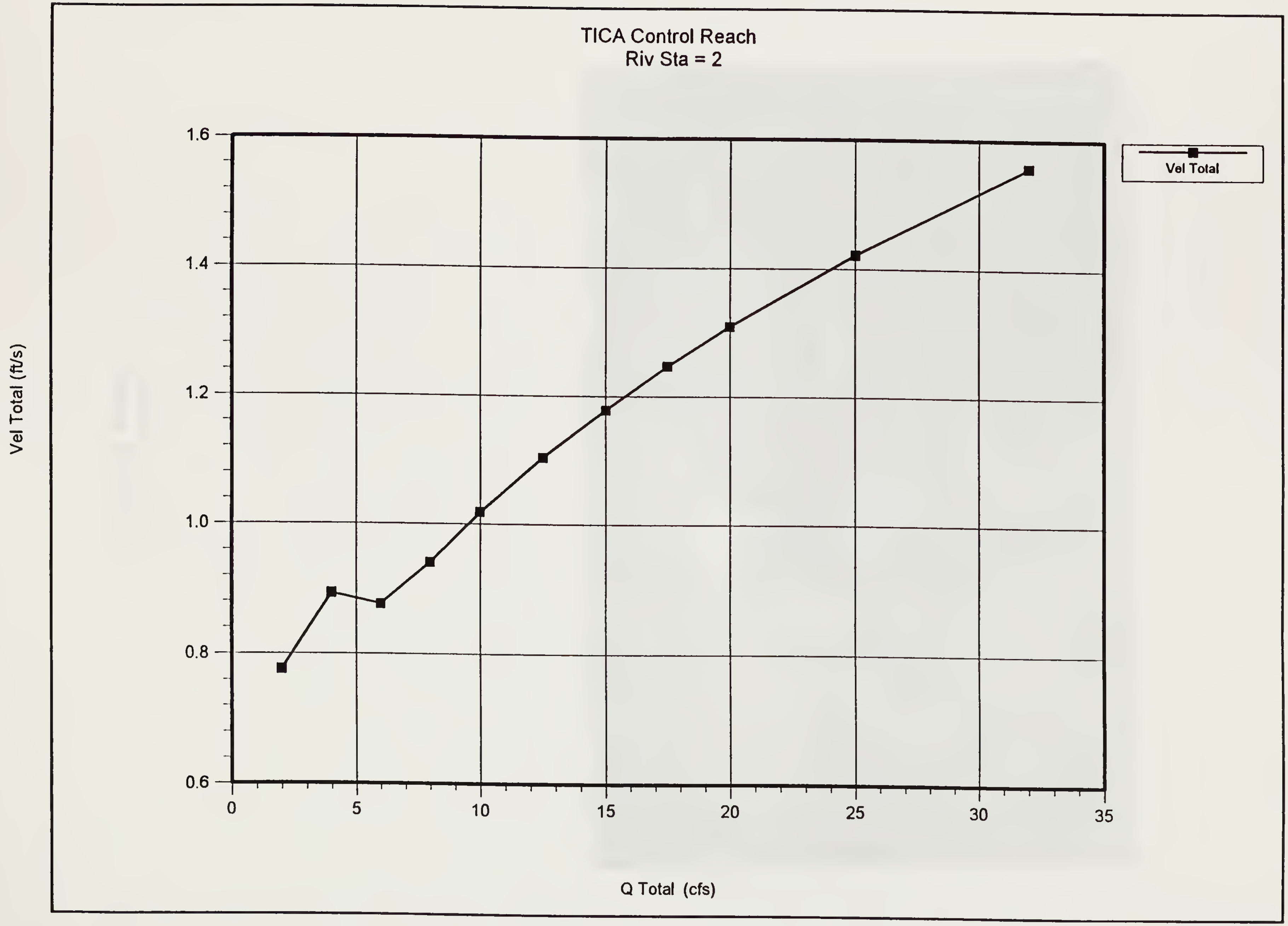
TICA Control Reach
Riv Sta = 2
Top Width
Top Width (ft)
Q Total (cfs)
30
25
20
15
10
5
0
5
10
15
20
25
30
35



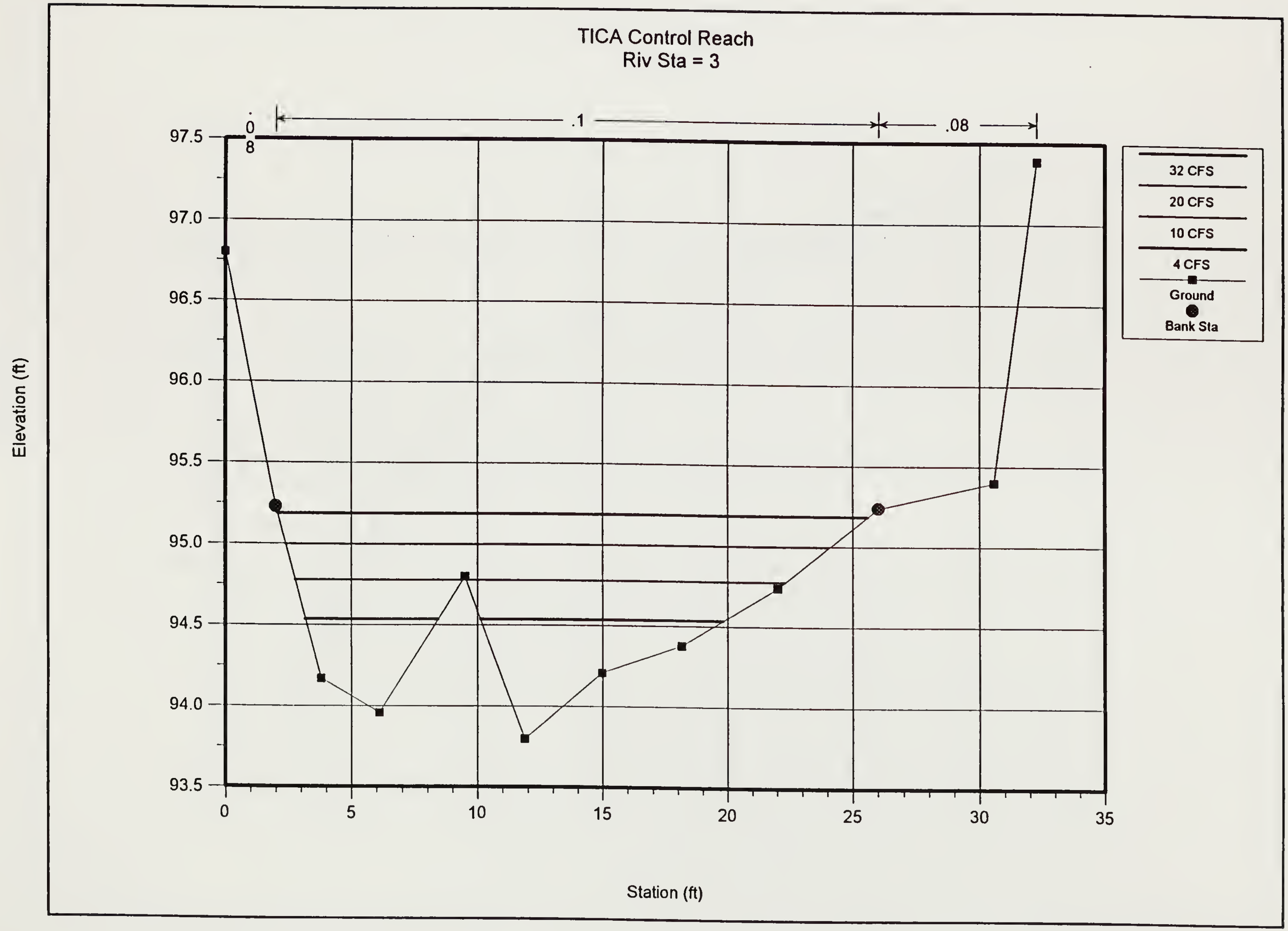
TICA Control Reach
Riv Sta = 2
Max Chl Dpth
Max Chl Dpth (ft)
Q Total (cfs)
1.4
1.2
1.0
0.8
0.6
0.4
0
5
10
15
20
25
30
35



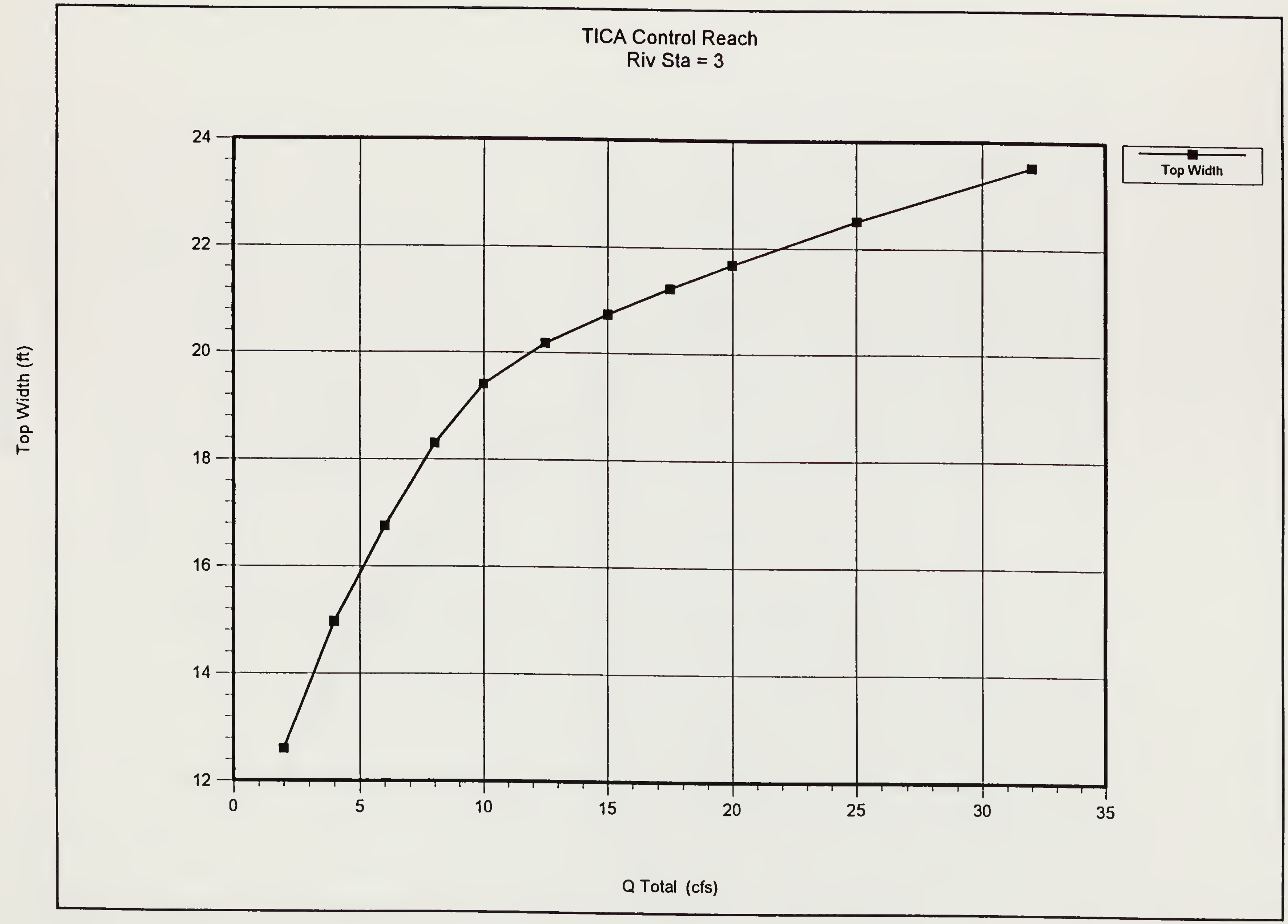
TICA Control Reach
Riv Sta = 2
Max Chl Dpth
Max Chl Dpth (ft)
1.4
1.2
1.0
0.8
0.6
0.4
0
5
10
15
20
25
30
35
Q Total (cfs)


TICA Control Reach
Riv Sta = 2
Vel Total
Vel Total (ft/s)
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)

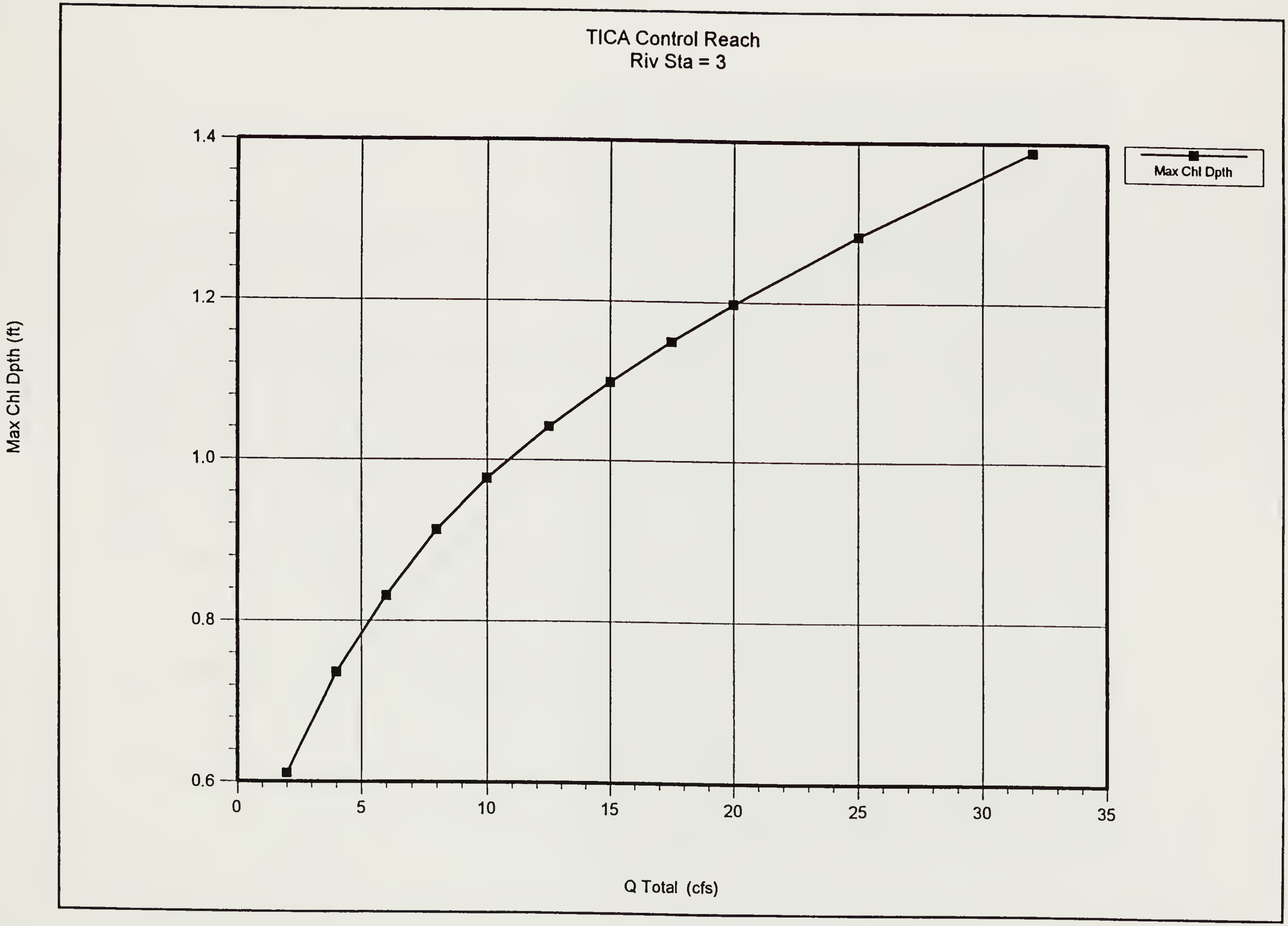
Control Reach
Cross Section 3



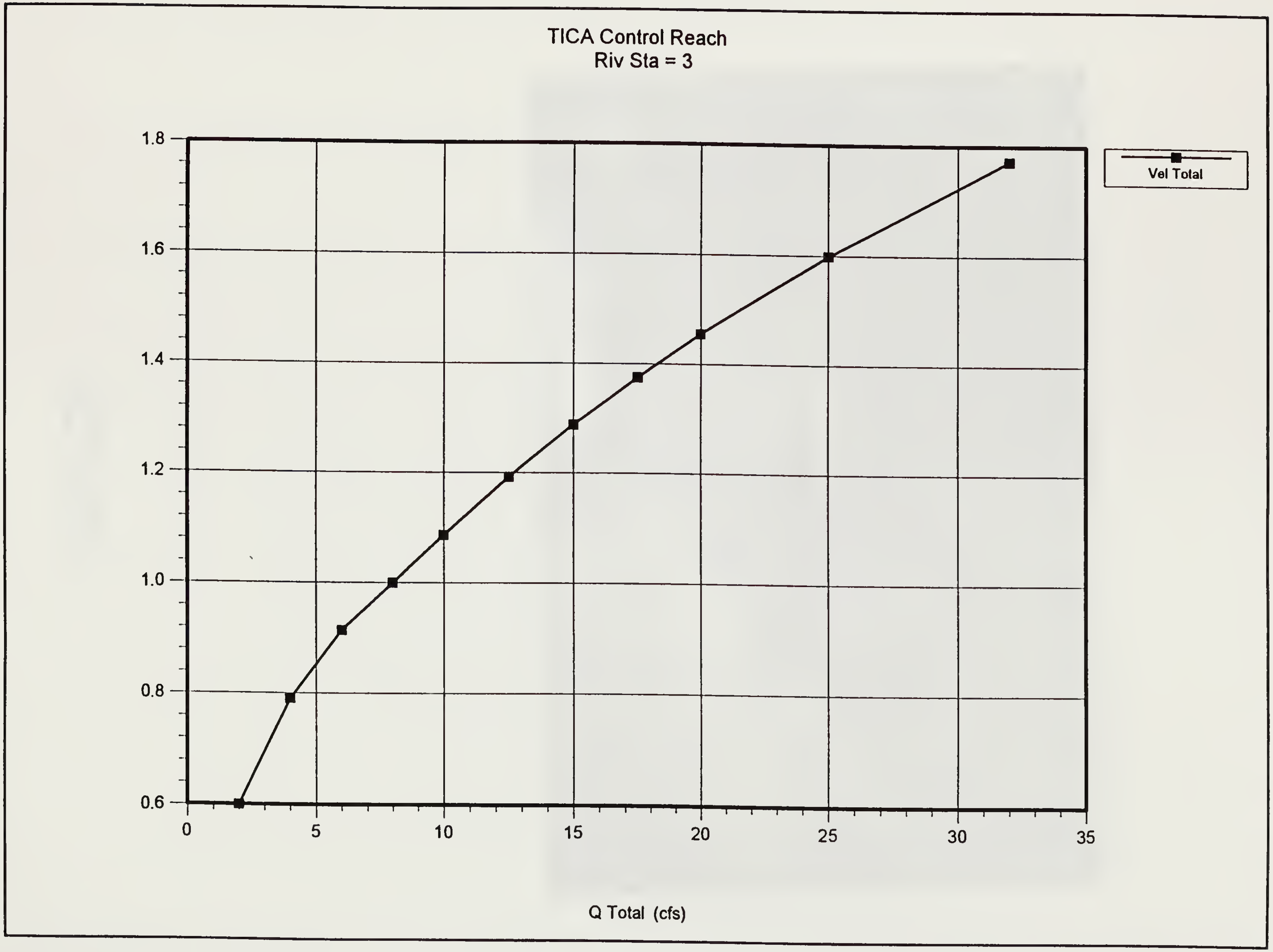
TICA Control Reach
Riv Sta = 3
.08
.1
.08
97.5
97.0
96.5
96.0
95.5
95.0
94.5
94.0
93.5
Elevation (ft)
0
5
10
15
20
25
30
35
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta



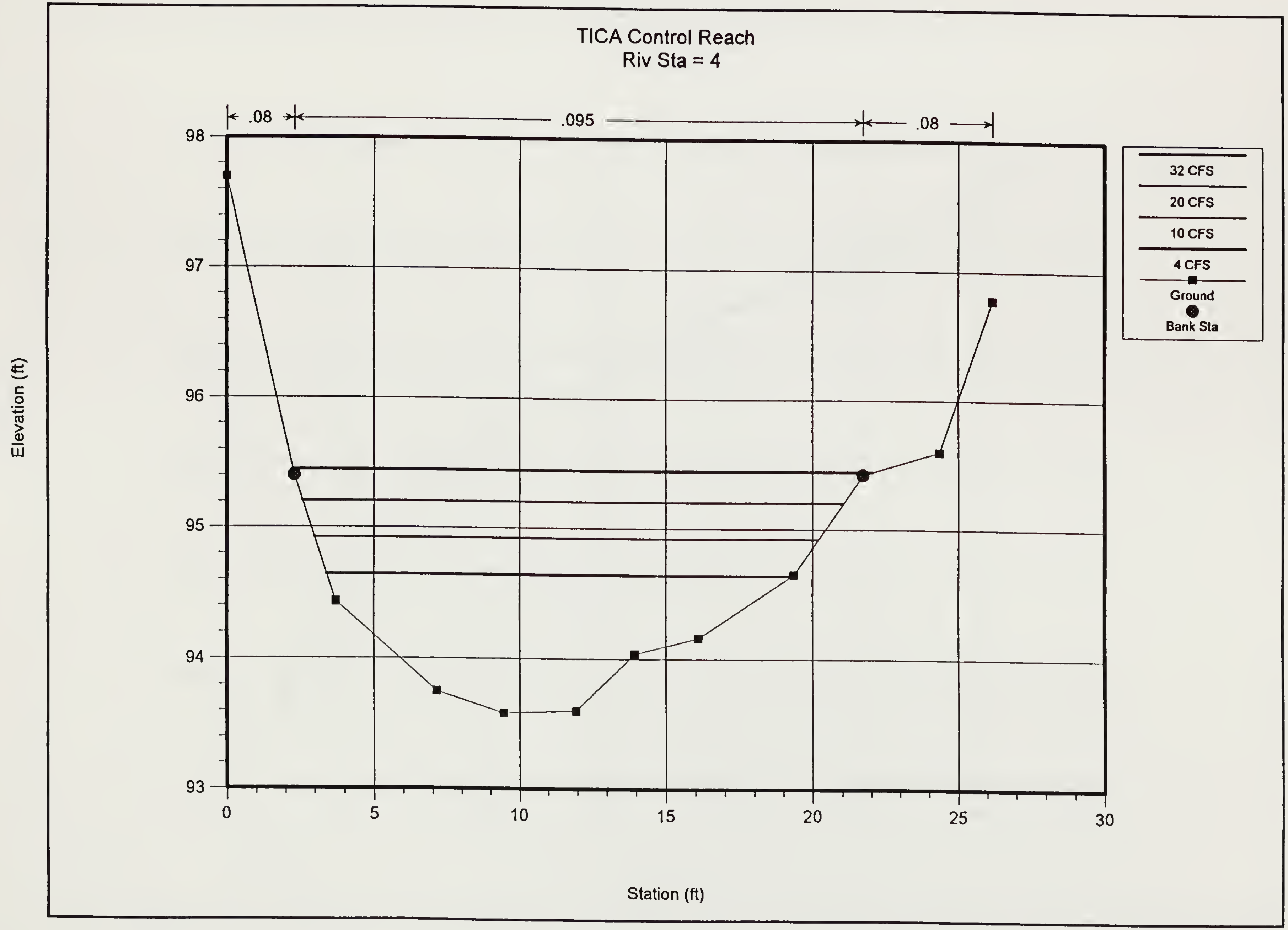
TICA Control Reach
Riv Sta = 3
Top Width (ft)
24
22
20
18
16
14
12
0
5
10
15
20
25
30
35
Q Total (cfs)
Top Width



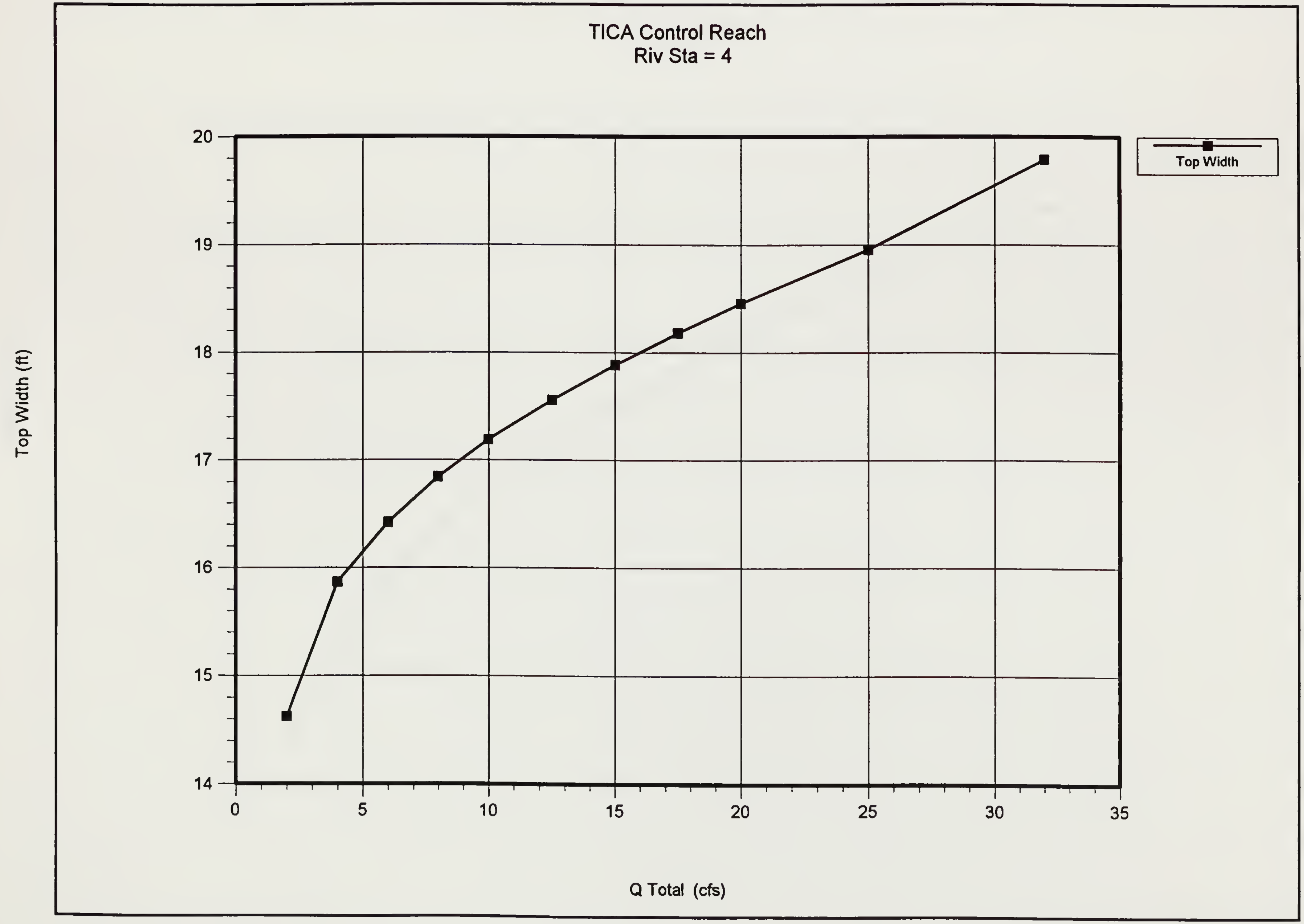
TICA Control Reach
Riv Sta = 3
Max Chl Dpth
Max Chl Dpth (ft)
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)


TICA Control Reach
Riv Sta = 3
Vel Total (ft/s)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)
Vel Total

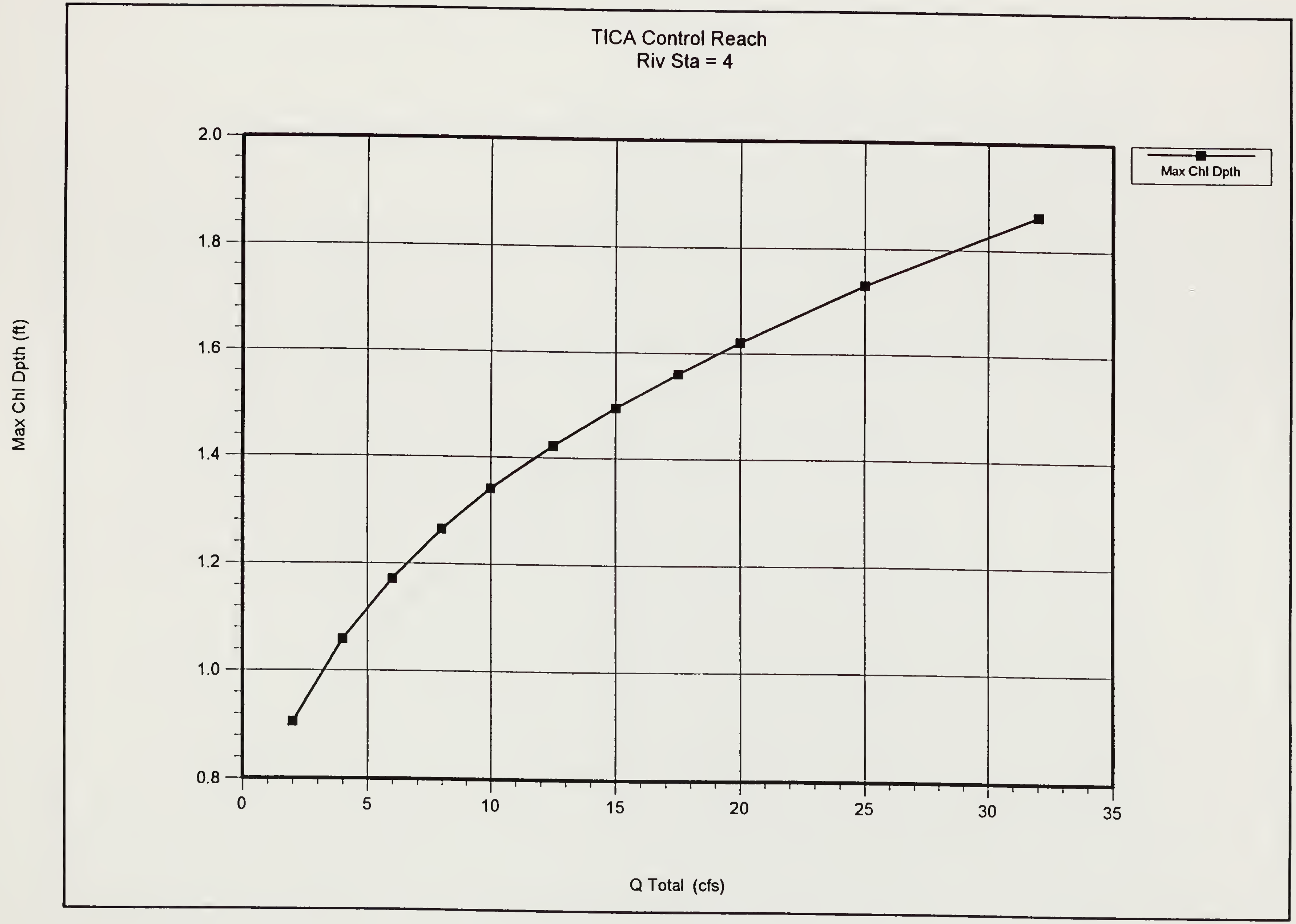
Control Reach
Cross Section 4



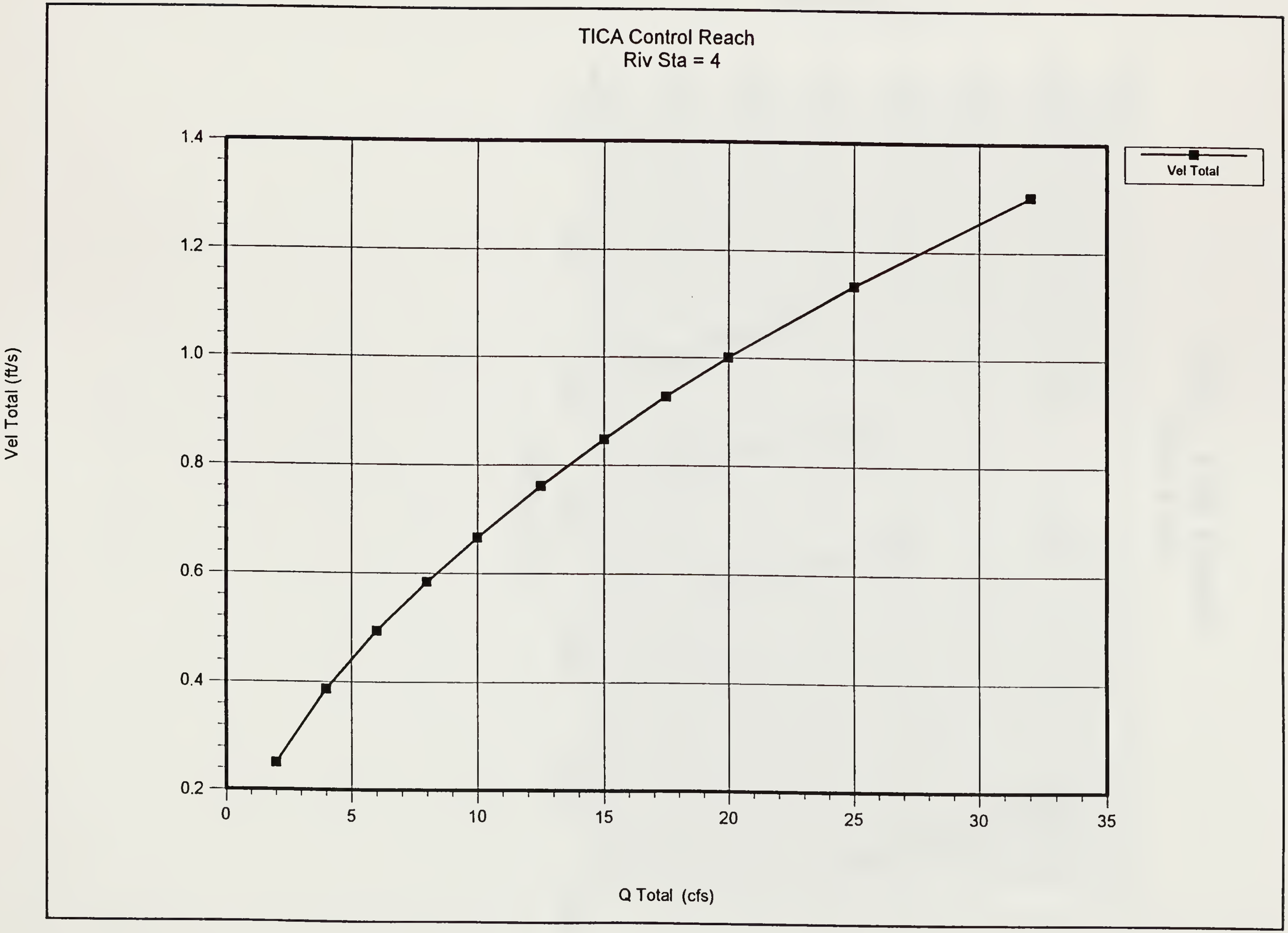
TICA Control Reach
Riv Sta = 4
.08
.095
.08
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
Elevation (ft)
98
97
96
95
94
93
Station (ft)
0
5
10
15
20
25
30



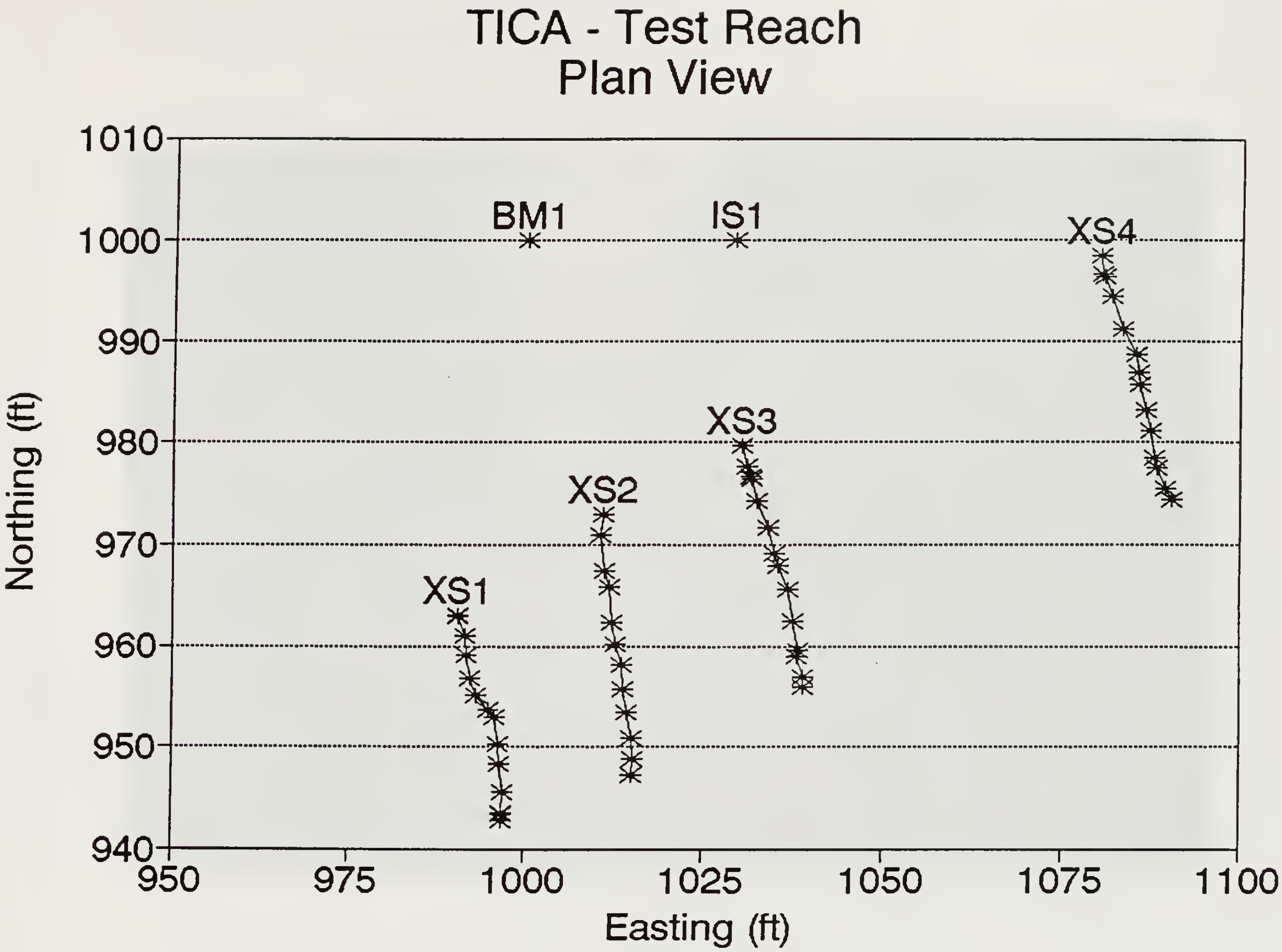
TICA Control Reach
Riv Sta = 4
Top Width
Top Width (ft)
Q Total (cfs)
20
19
18
17
16
15
14
0
5
10
15
20
25
30
35



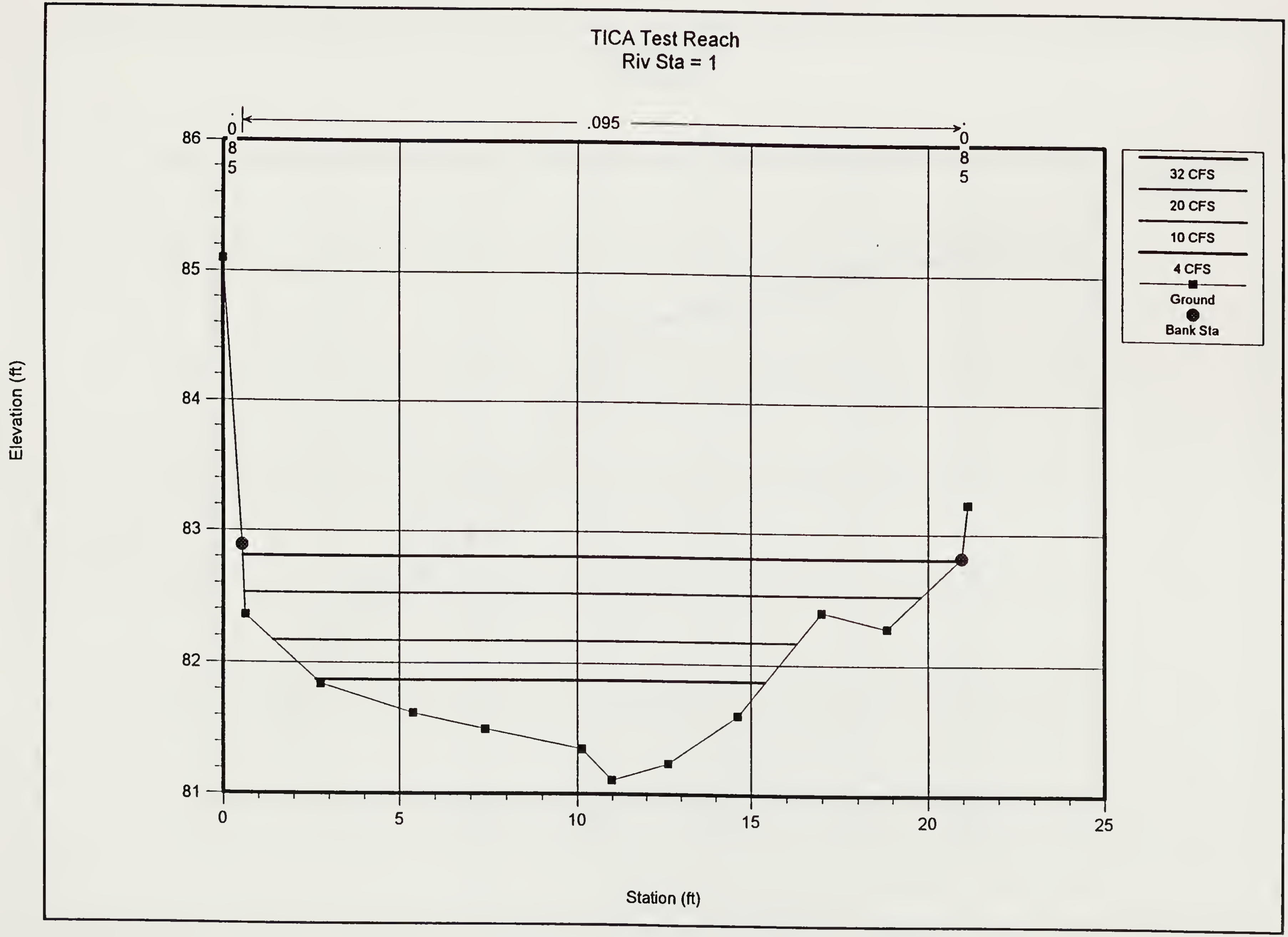
TICA Control Reach
Riv Sta = 4
Max Chl Dpth
Max Chl Dpth (ft)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0
5
10
15
20
25
30
35
Q Total (cfs)

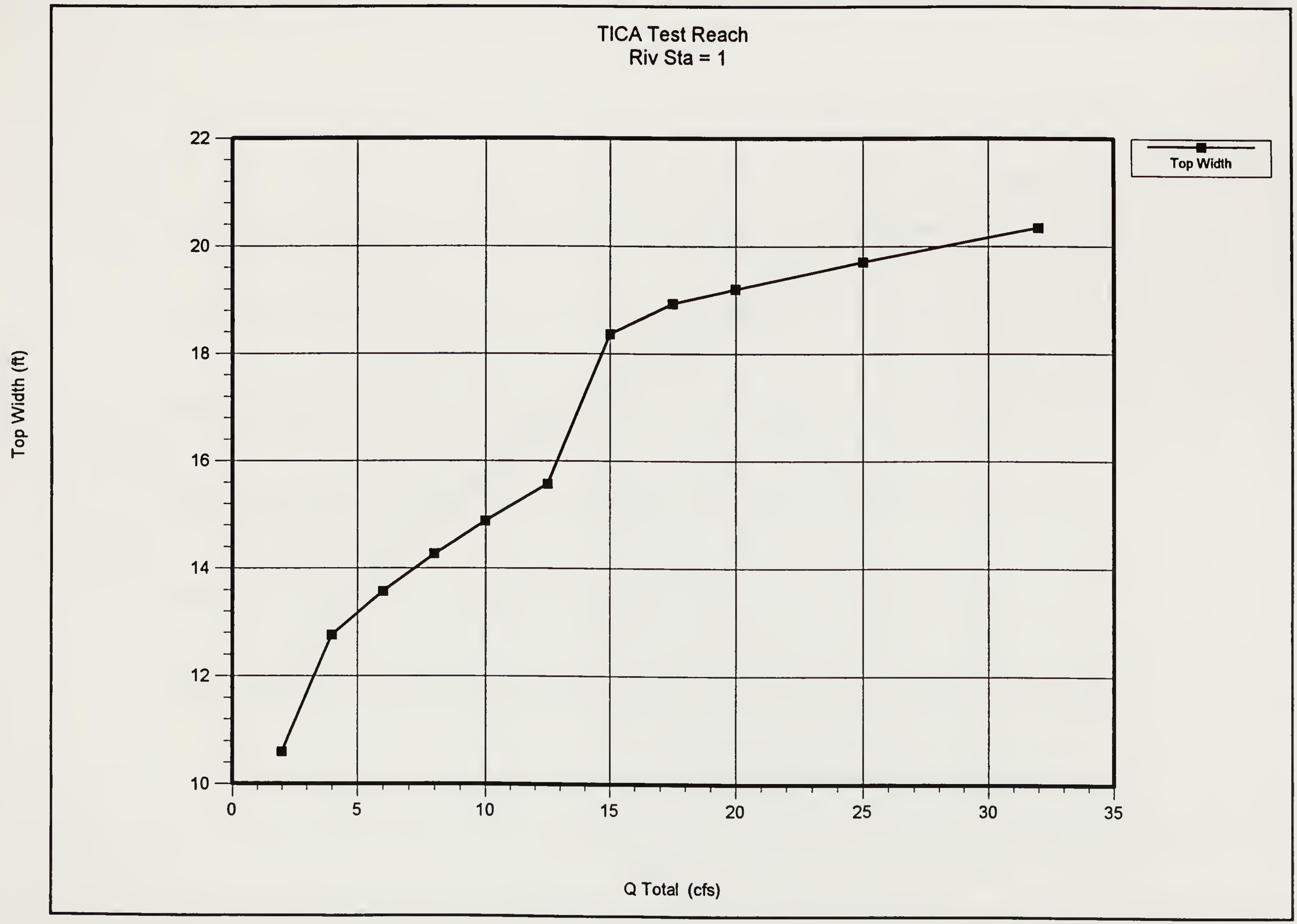


TICA Control Reach
Riv Sta = 4
Vel Total
Vel Total (ft/s)
Q Total (cfs)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
5
10
15
20
25
30
35

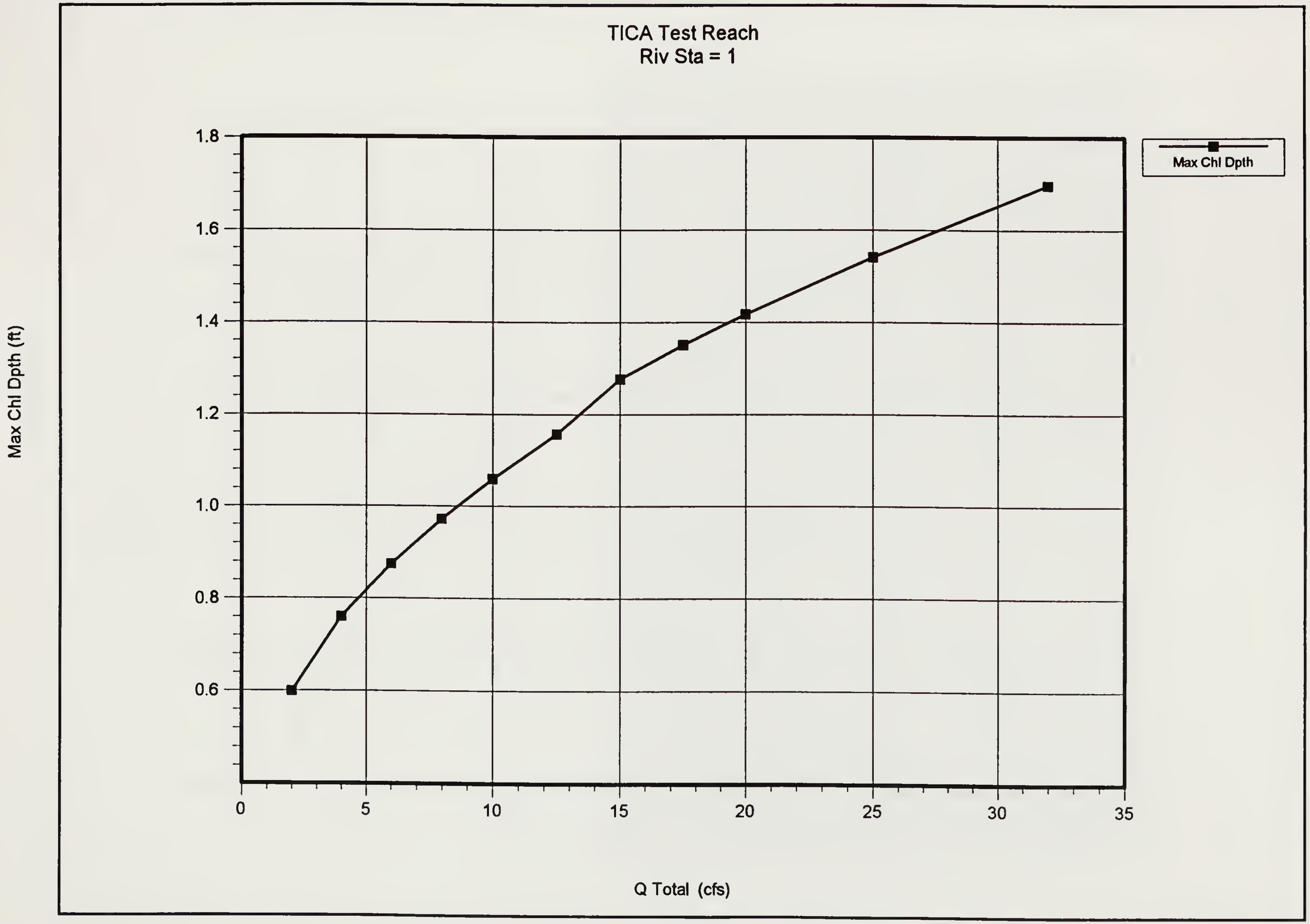

TICA - Test Reach
Plan View
BM1
IS1
XS1
XS2
XS3
XS4
Northing (ft)
Easting (ft)
1010
1000
990
980
970
960
950
940
950
975
1000
1025
1050
1075
1100

Test Reach
Cross Section 1

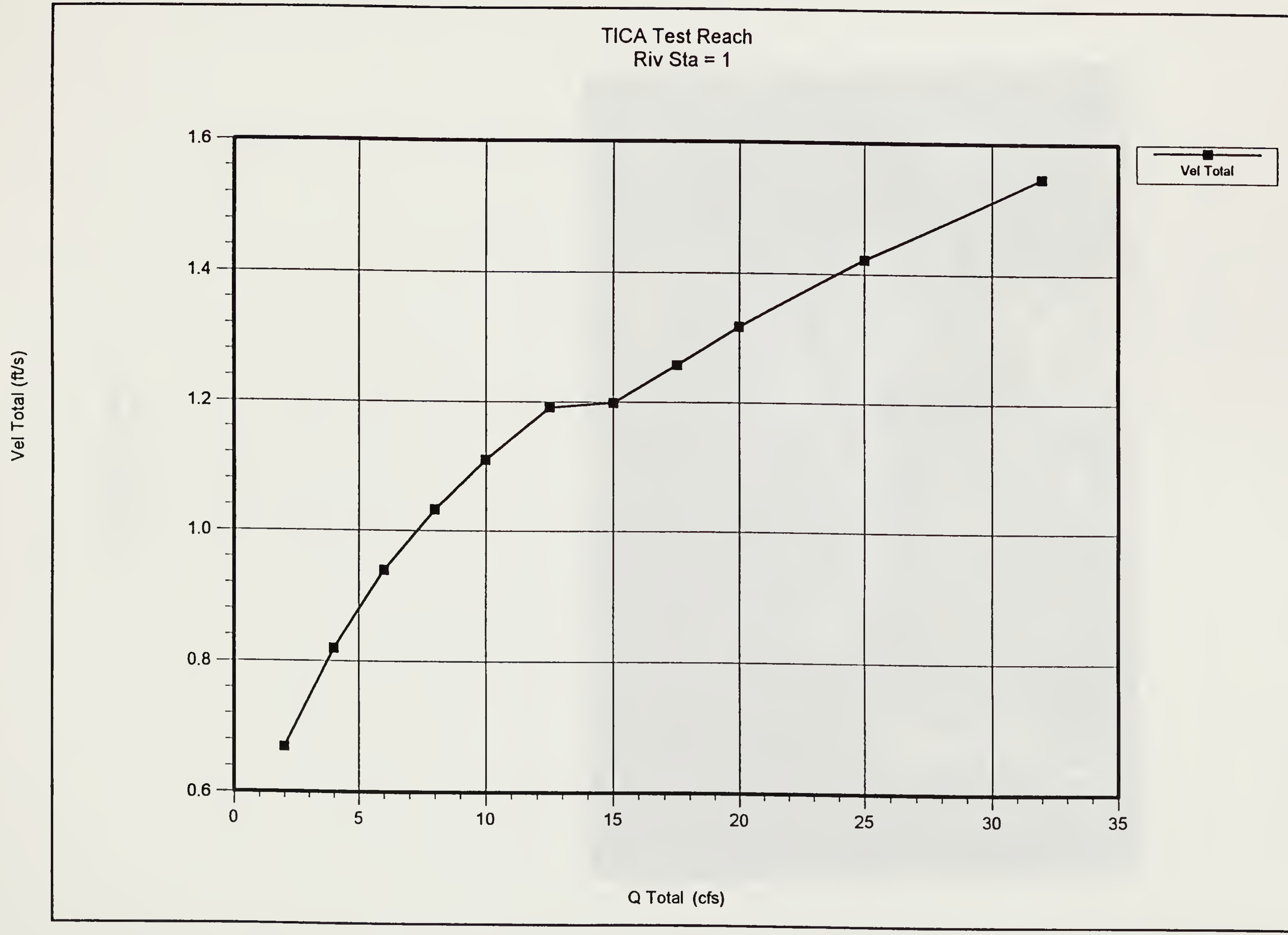

TICA Test Reach
Riv Sta = 1
.095
0
8
5
0
8
5
86
85
84
83
82
81
Elevation (ft)
0
5
10
15
20
25
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta



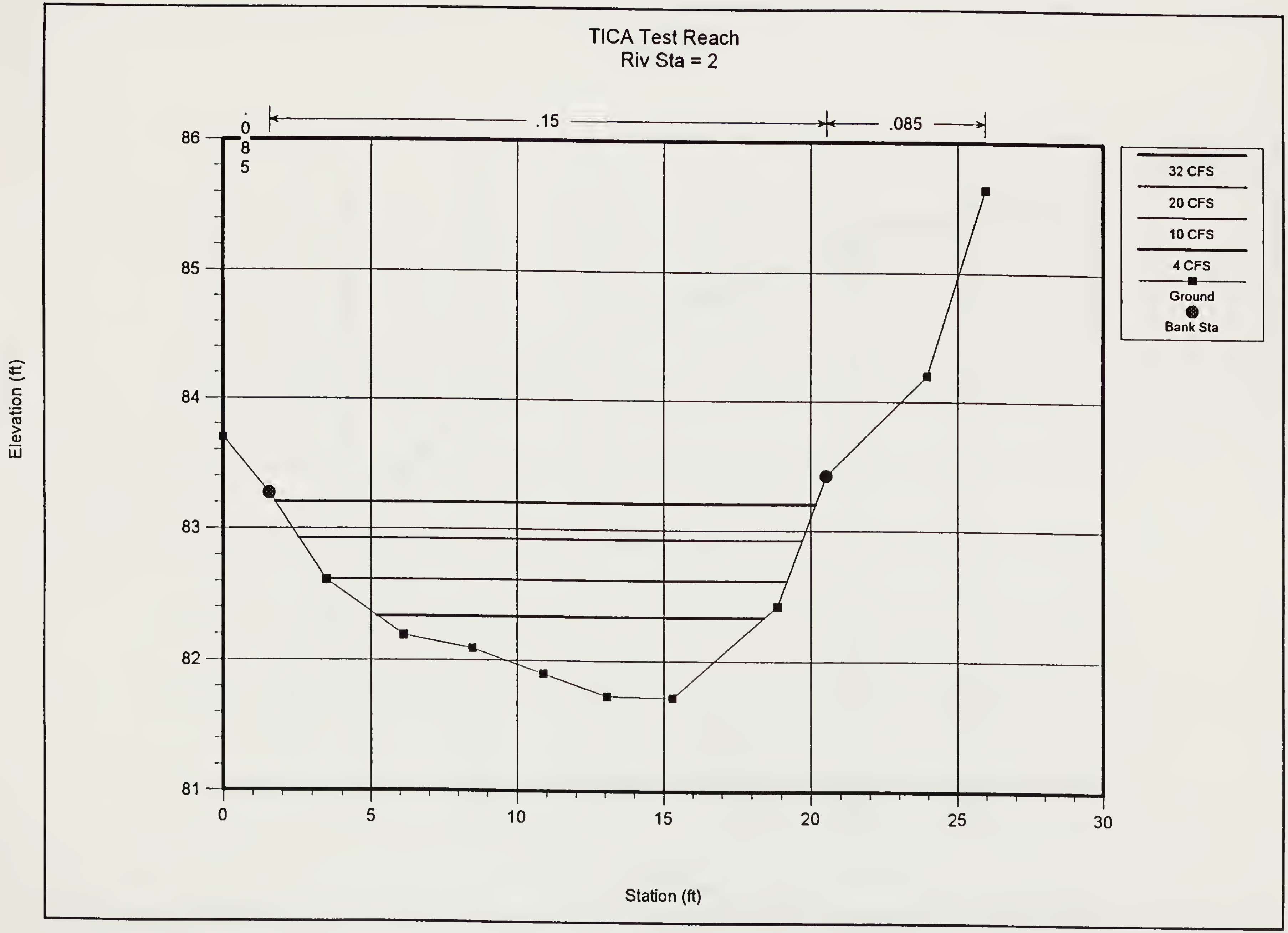
TICA Test Reach
Riv Sta = 1
Top Width
Top Width (ft)
Q Total (cfs)
22
20
18
16
14
12
10
0
5
10
15
20
25
30
35



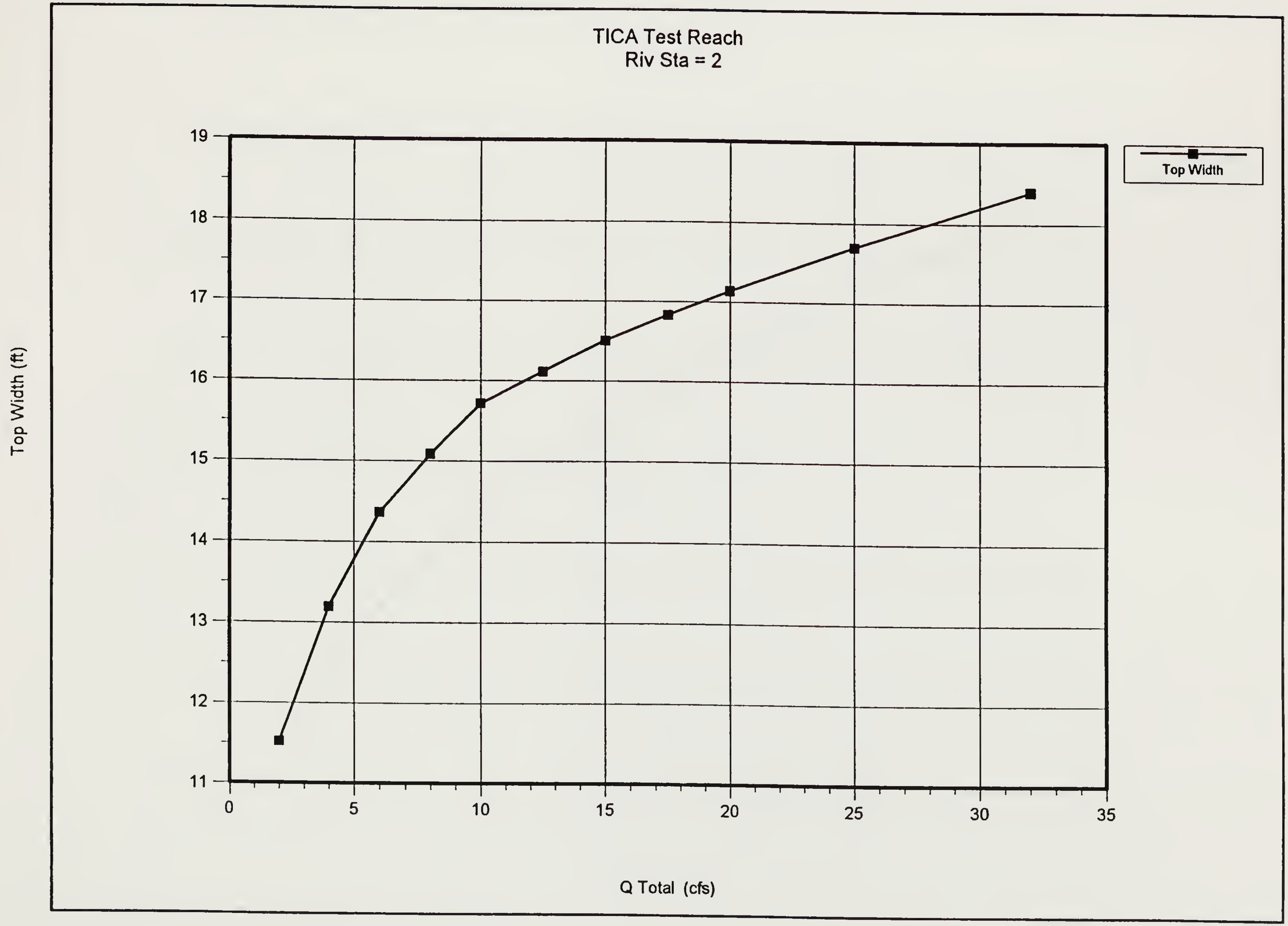
TICA Test Reach
Riv Sta = 1
Max Chl Dpth
Max Chl Dpth (ft)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)


TICA Test Reach
Riv Sta = 1
Vel Total
Vel Total (ft/s)
Q Total (cfs)
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35

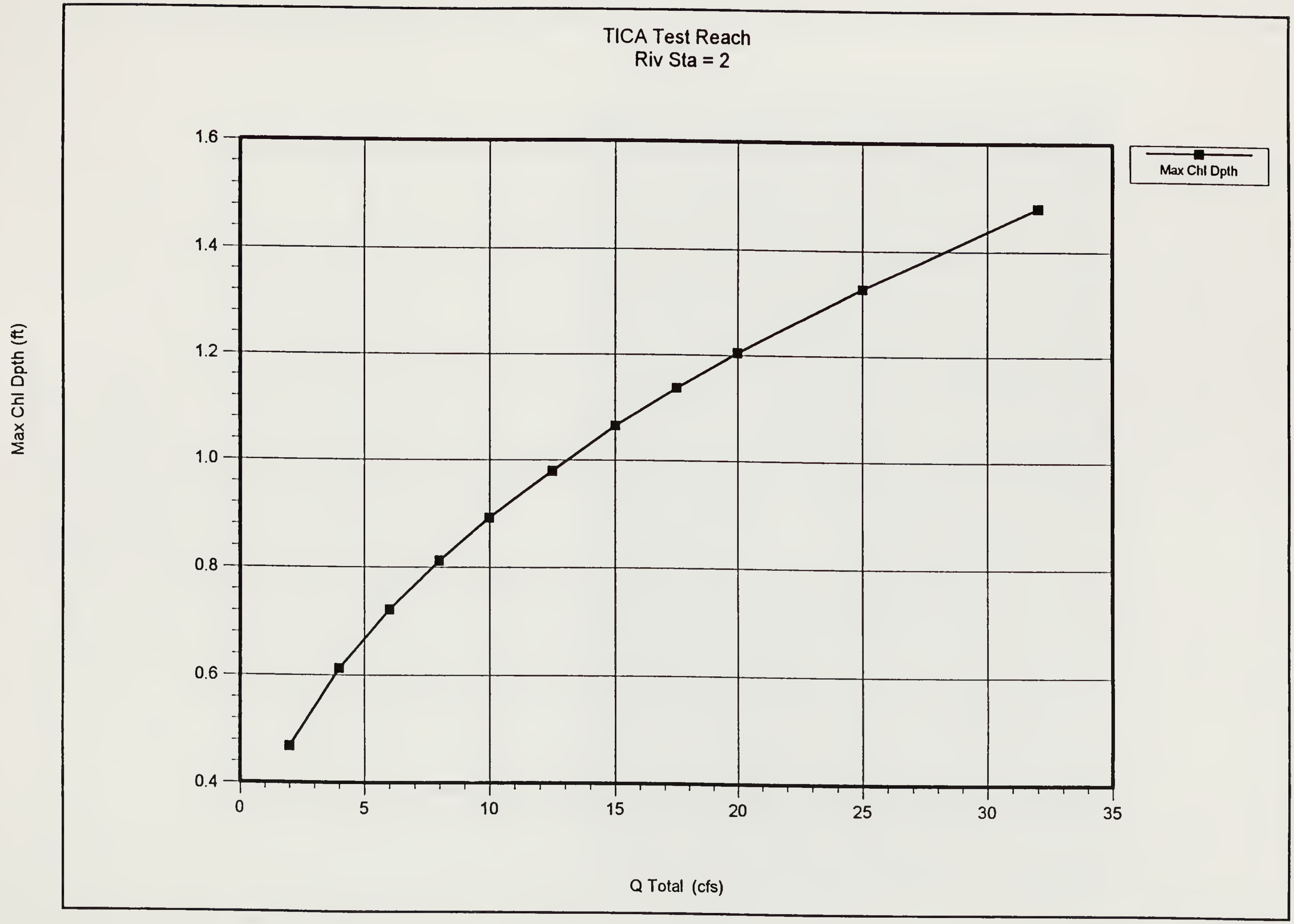
Test Reach
Cross Section 2



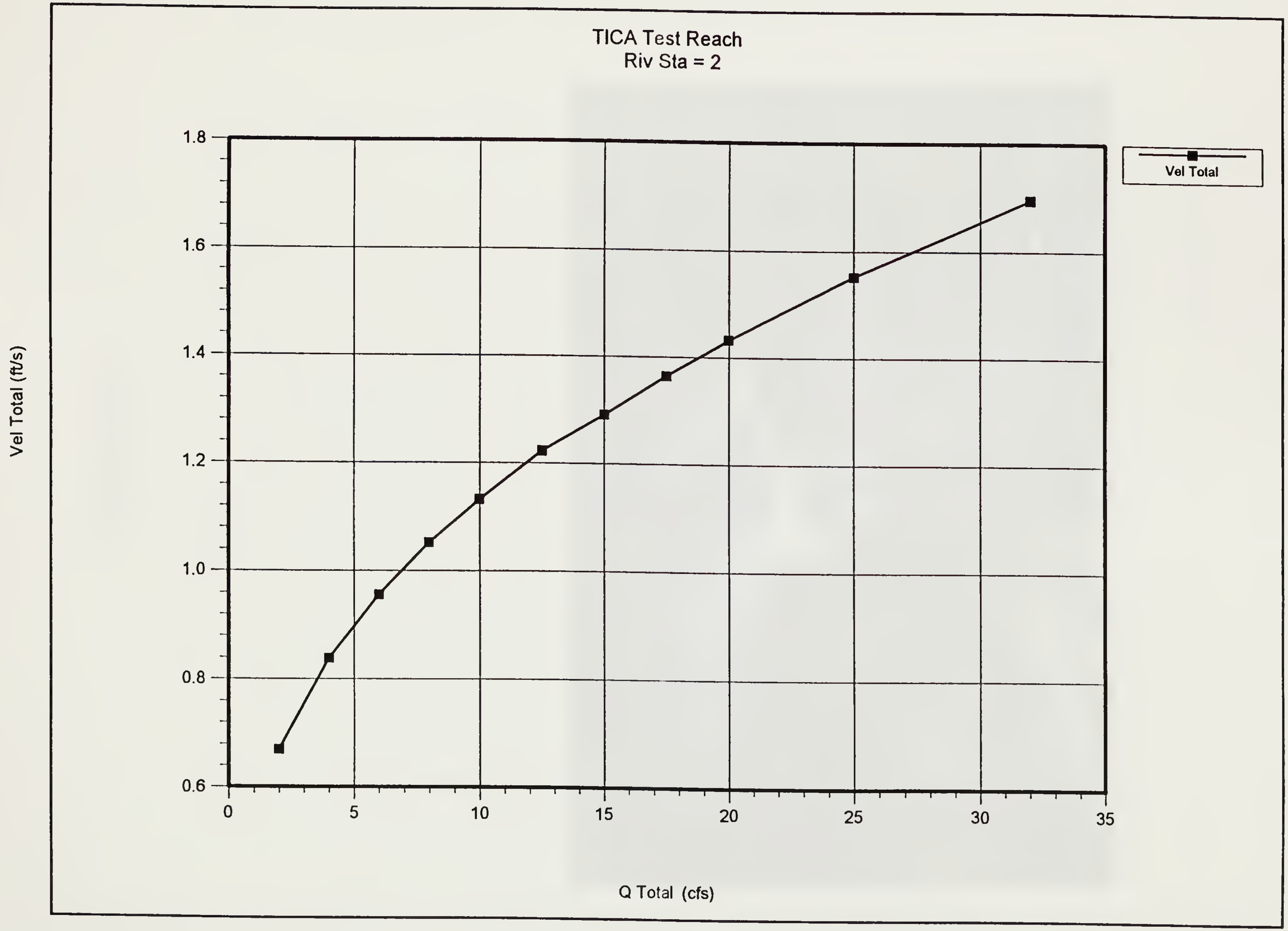
TICA Test Reach
Riv Sta = 2
.085
.15
.085
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
Elevation (ft)
86
85
84
83
82
81
0
5
10
15
20
25
30
Station (ft)



TICA Test Reach
Riv Sta = 2
Top Width
Top Width (ft)
Q Total (cfs)
19
18
17
16
15
14
13
12
11
0
5
10
15
20
25
30
35

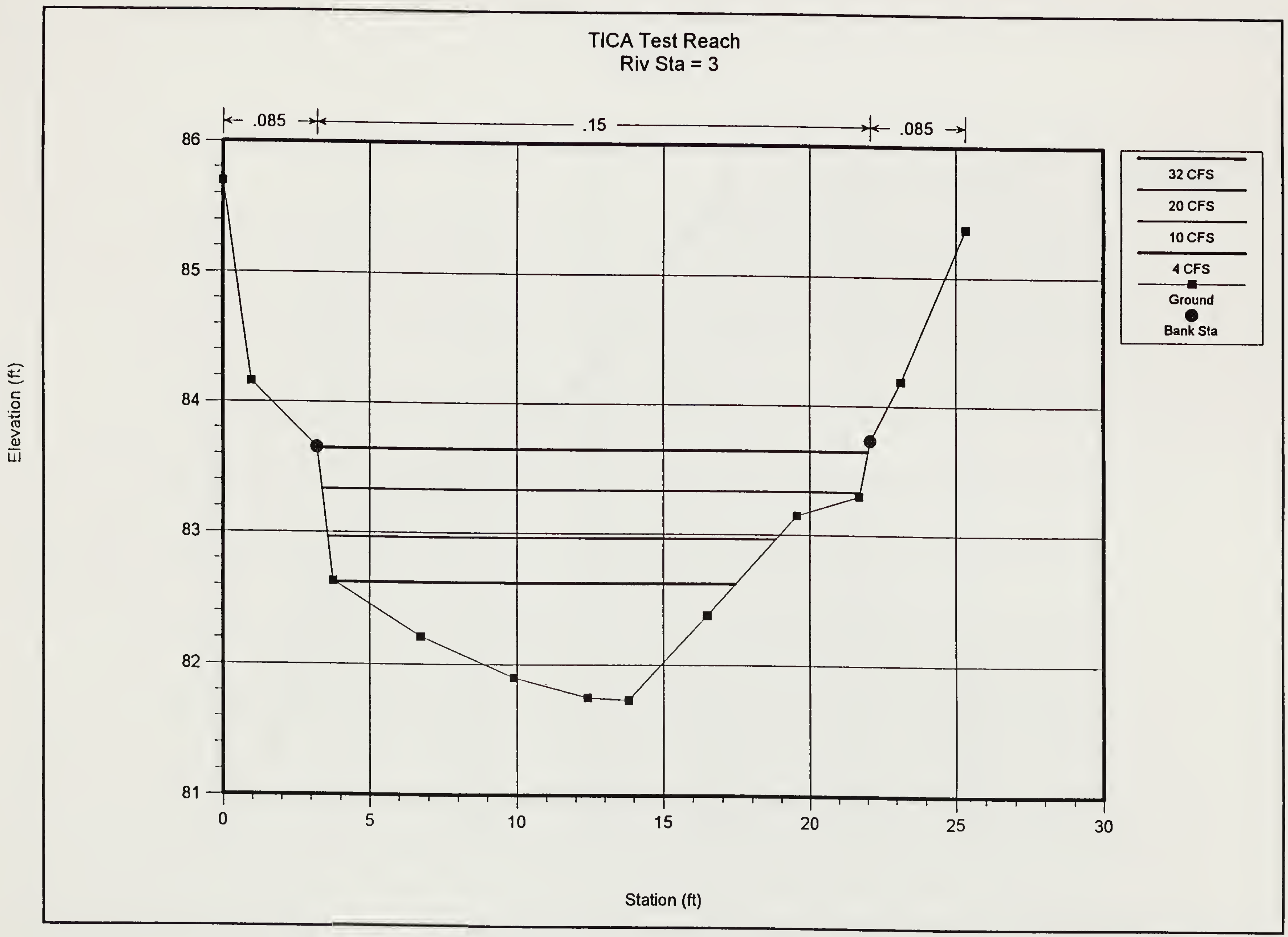


TICA Test Reach
Riv Sta = 2
Max Chl Dpth
Max Chl Dpth (ft)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
5
10
15
20
25
30
35
Q Total (cfs)

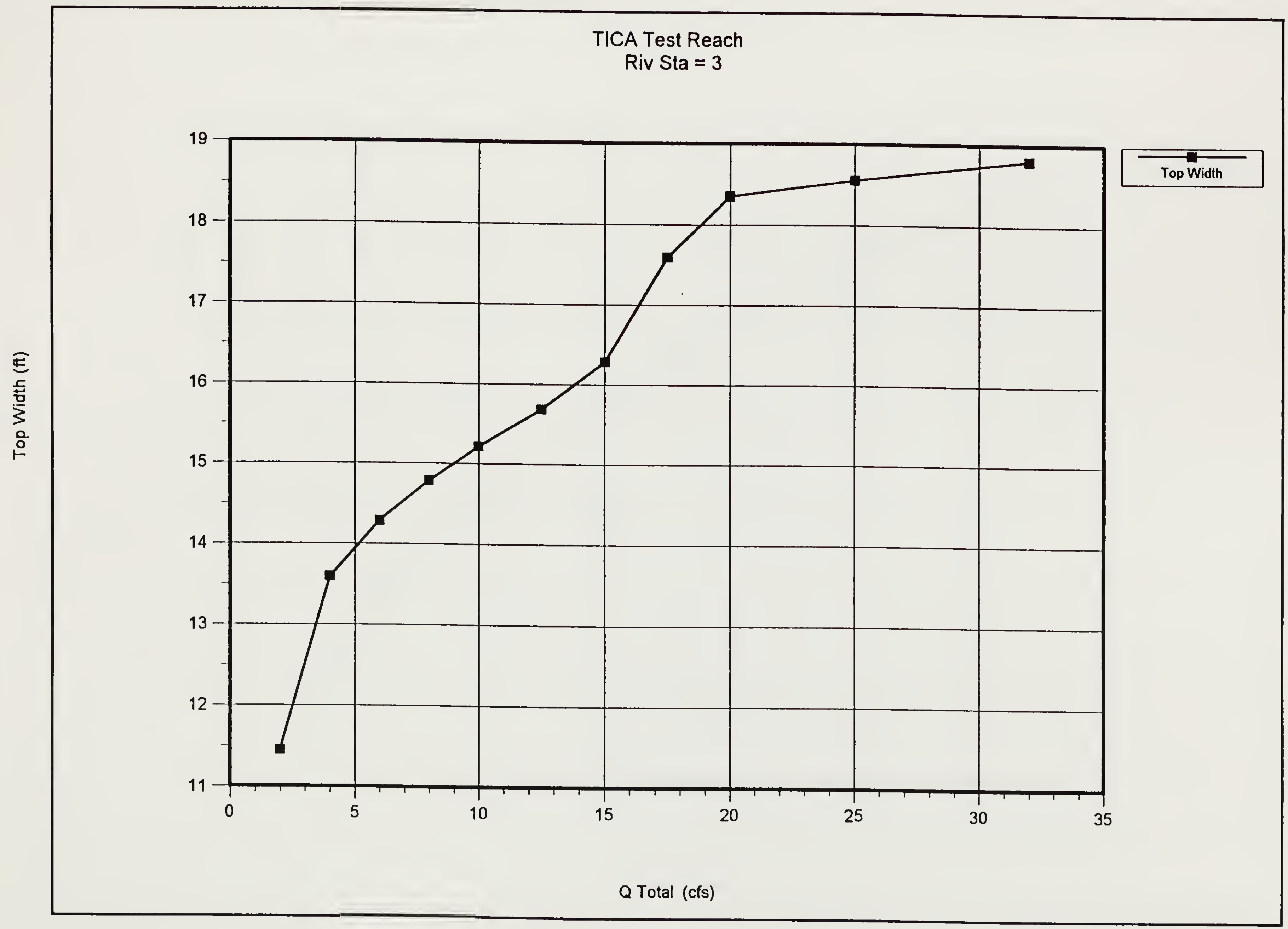


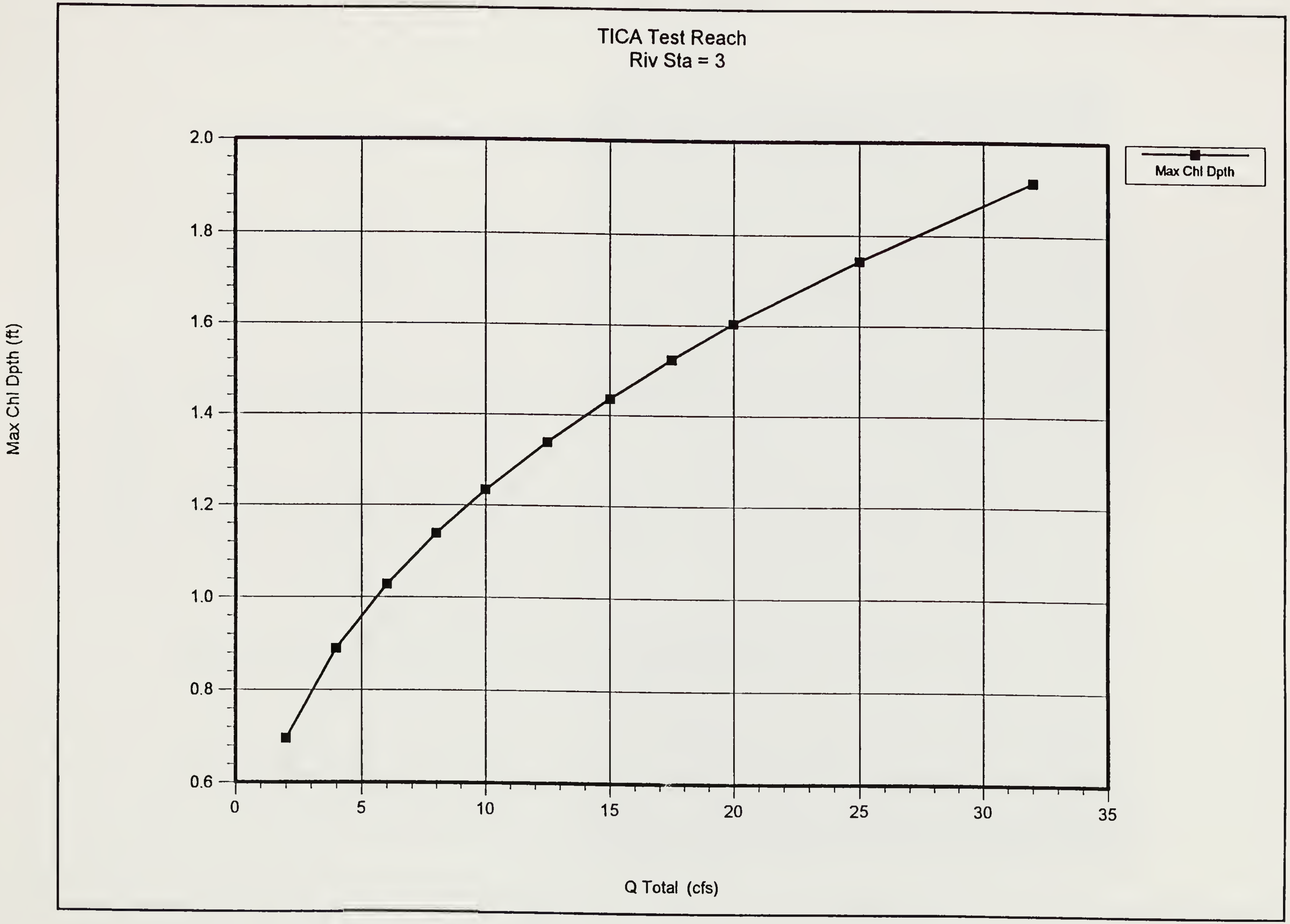
TICA Test Reach
Riv Sta = 2
Vel Total
Vel Total (ft/s)
Q Total (cfs)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35

Test Reach
Cross Section 3

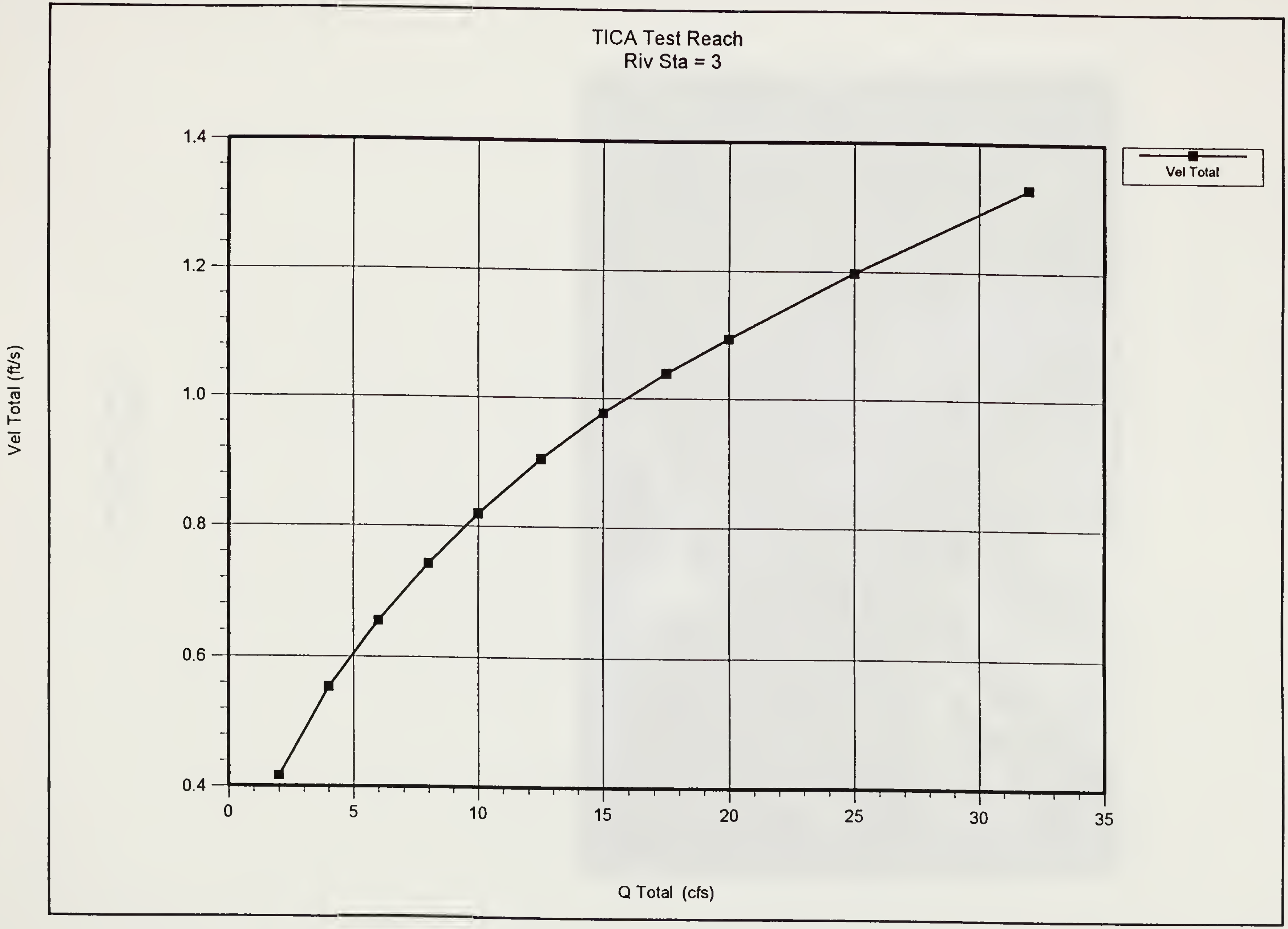


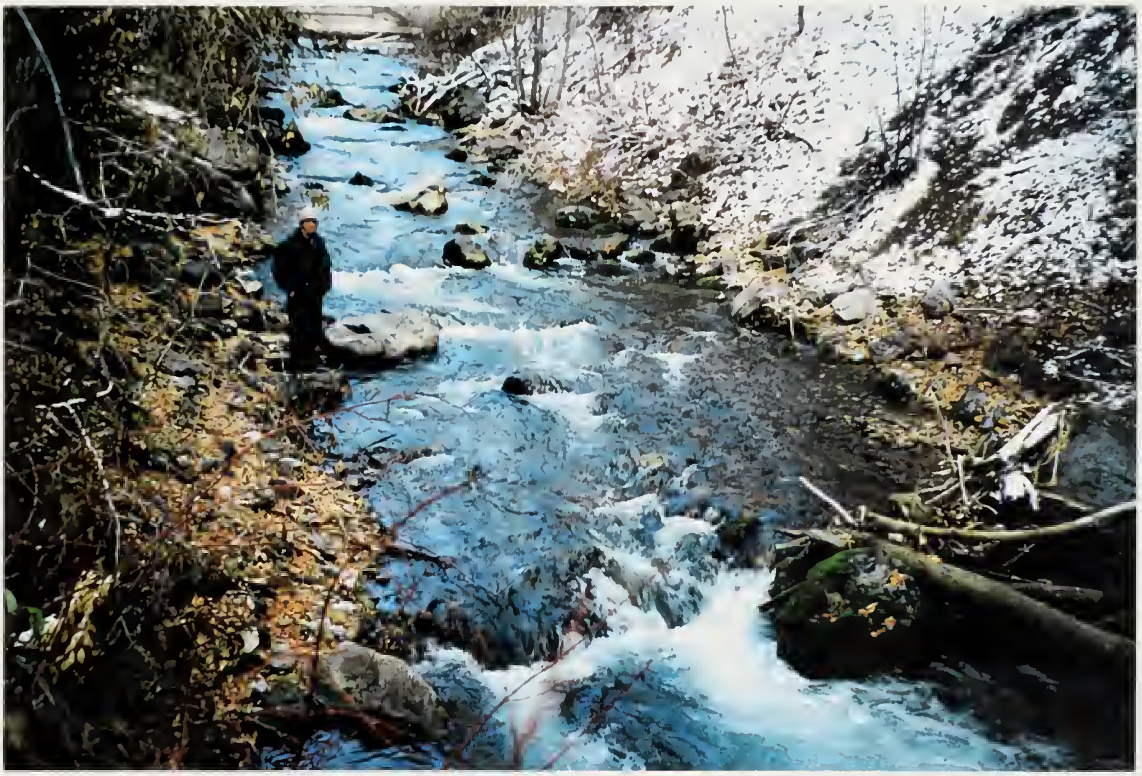
TICA Test Reach
Riv Sta = 3
.085
.15
.085
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta
Elevation (ft)
Station (ft)
86
85
84
83
82
81
0
5
10
15
20
25
30


TICA Test Reach
Riv Sta = 3
Top Width (ft)
Q Total (cfs)
Top Width
19
18
17
16
15
14
13
12
11
0
5
10
15
20
25
30
35

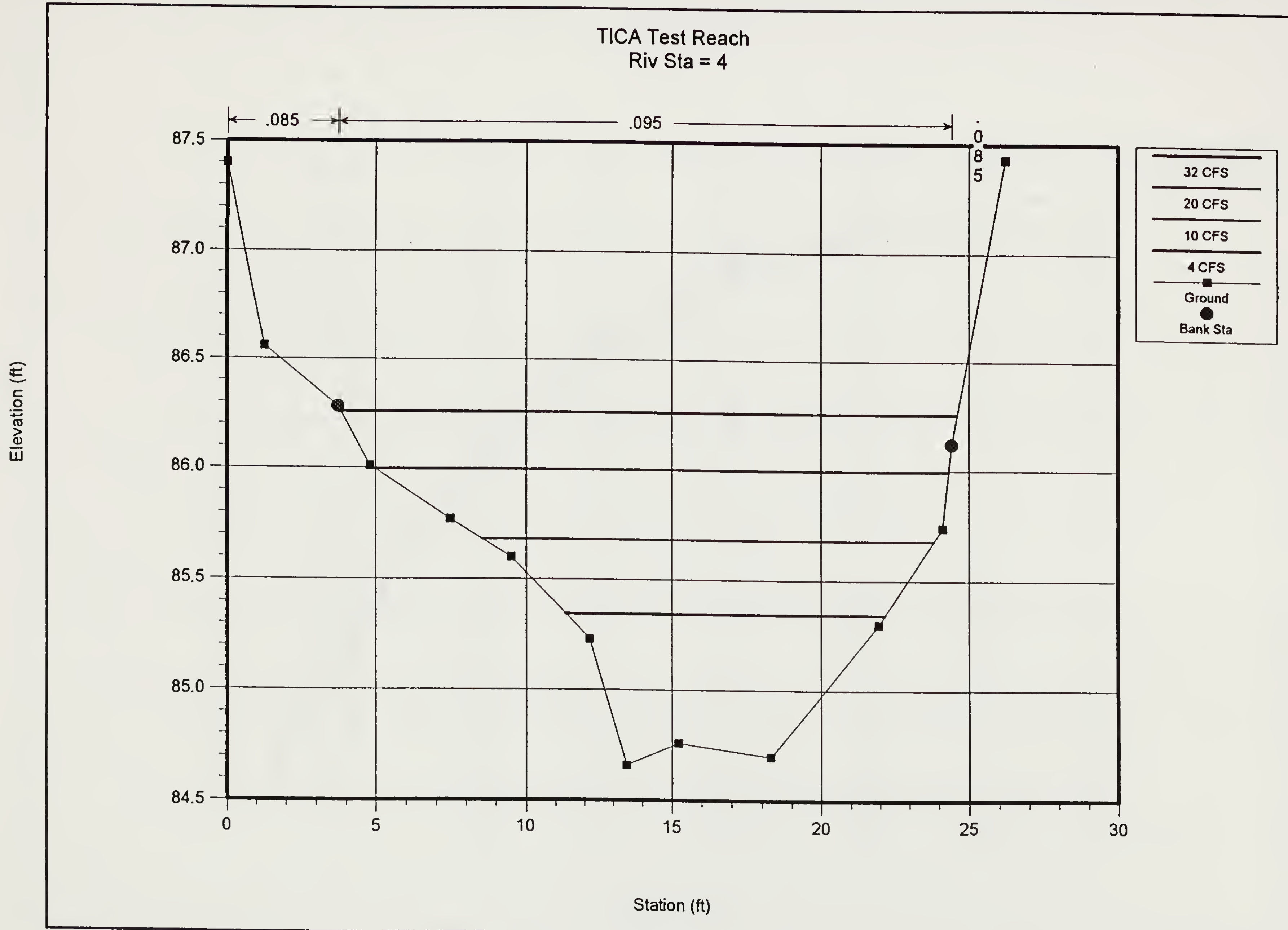


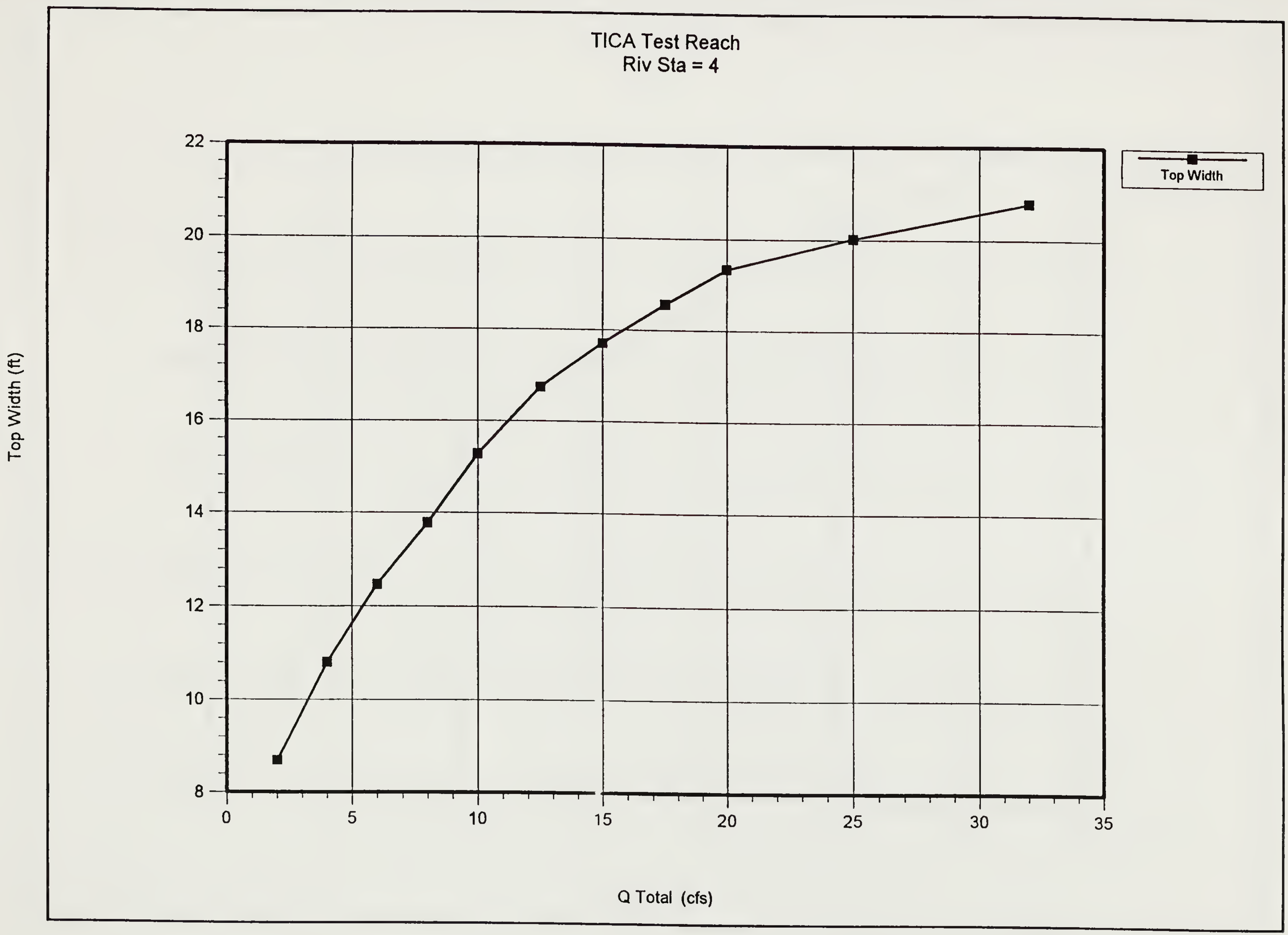
TICA Test Reach
Riv Sta = 3
Max Chl Dpth
Max Chl Dpth (ft)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35
Q Total (cfs)

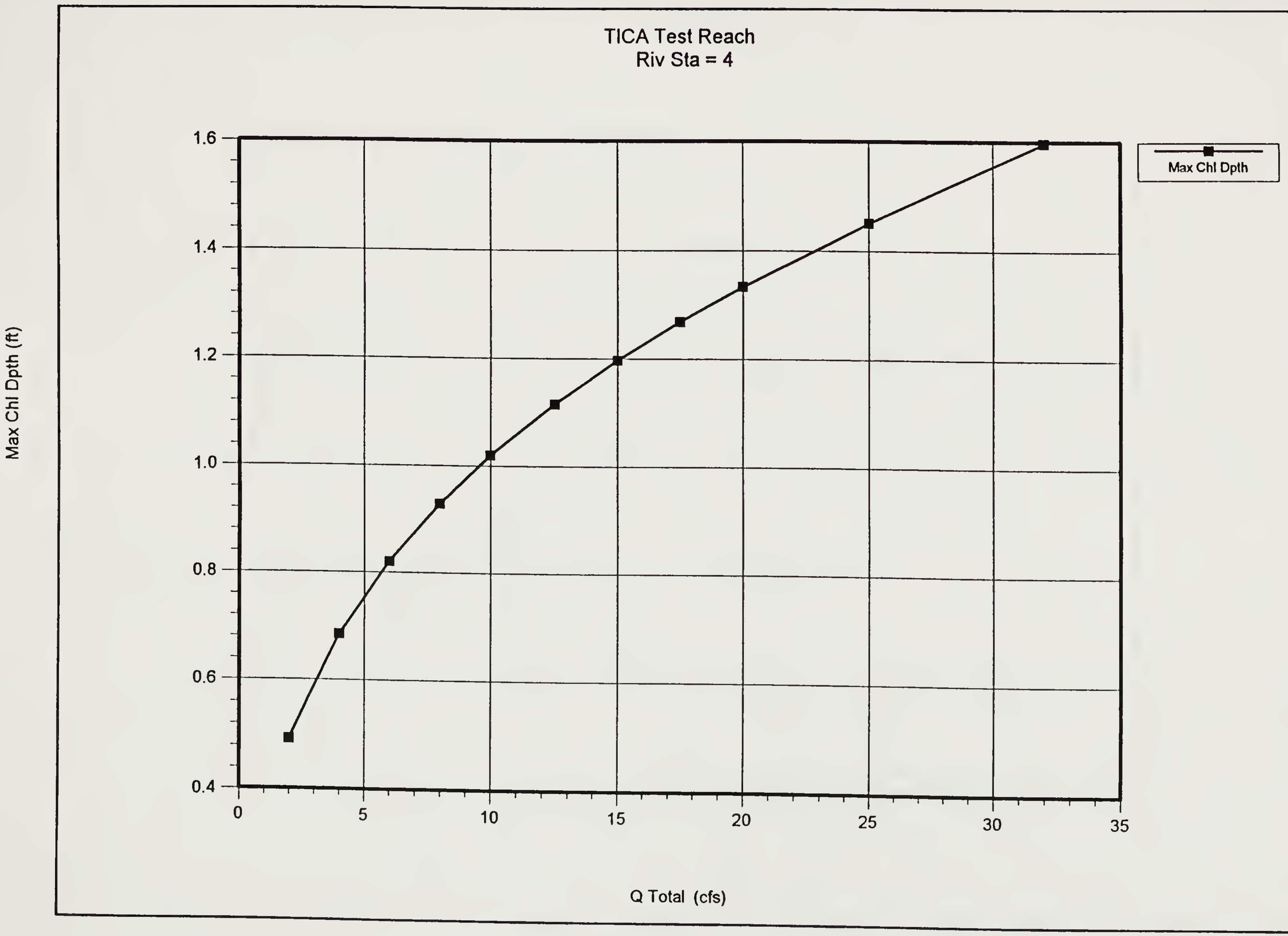

TICA Test Reach
Riv Sta = 3
Vel Total (ft/s)
1.4
1.2
1.0
0.8
0.6
0.4
0
5
10
15
20
25
30
35
Q Total (cfs)
Vel Total



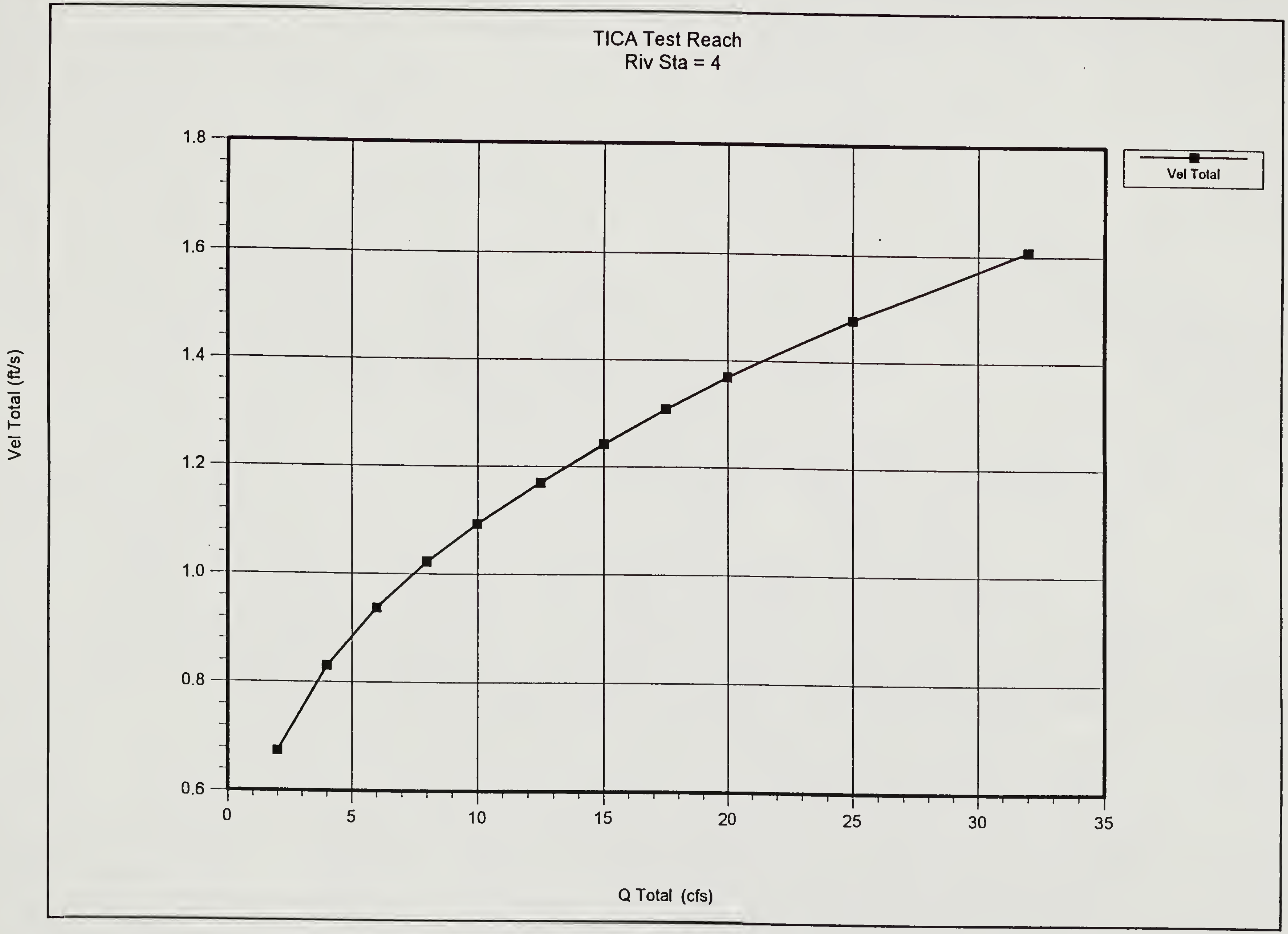
Test Reach
Cross Section 4


TICA Test Reach
Riv Sta = 4
.085
.095
.085
87.5
87.0
86.5
86.0
85.5
85.0
84.5
Elevation (ft)
0
5
10
15
20
25
30
Station (ft)
32 CFS
20 CFS
10 CFS
4 CFS
Ground
Bank Sta


TICA Test Reach
Riv Sta = 4
Top Width
Top Width (ft)
Q Total (cfs)
22
20
18
16
14
12
10
8
0
5
10
15
20
25
30
35



TICA Test Reach
Riv Sta = 4
Max Chl Dpth
Max Chl Dpth (ft)
Q Total (cfs)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
5
10
15
20
25
30
35


TICA Test Reach
Riv Sta = 4
Vel Total
Vel Total (ft/s)
Q Total (cfs)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30
35